State of California

Department of Education Bulletin

No. 3 **February 1** **1937**

An Introduction to the Problems of Sight Conservation

A Handbook for Teachers and School Executives

R. S. French

Principal of the California School for the Blind and
President of the Sight Conservation Council
of Northern California


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The State of California Department of Education Bulletin is issued twice a month by the California State Department of Education.

Entered as second-class matter January 1, 1932, at the Post Office at Sacramento, California, under the Act of August 24, 1912.

39444

CALIFORNIA STATE PRINTING OFFICE
GEORGE H. MOORE, STATE PRINTER
SACRAMENTO, 1937

FOREWORD

With the development and extension of its functions, the State Department of Education has assumed among its other activities that of leadership in specific and highly specialized fields of education.

In 1921, the State School for the Blind and the State School for the Deaf were placed under the administrative control of the Department. In 1929, the principals of these schools were added to the staff of the Department in the Division of Special Education as Chief of the Bureau for the Education of the Blind and Chief of the Bureau for the Education of the Deaf, respectively. More recently the activities of the Department in the field of special education have been brought under the direction of a Commission for Special Education within the Department. The chiefs of the above named Bureaus are members of this Commission.

The functions and activities of the Department in the several special education fields are primarily those of leadership rather than of administration and control. This leadership involves the establishment of closer relations between the general public school system and those parts of the system which require segregation and special forms of instruction. At the present time the Department is particularly concerned with developing a better understanding of certain problems in special education on the part of school administrators and teachers and the general public. One means of accomplishing this objective lies in the publication of bulletins such as this.

Sight conservation has become, even in its restricted sense, a vital part of school organization. In the larger sense implied in the bulletin here offered to the public schools, sight conservation is the concern of all teachers, all parents, all children, all citizens.

The preparation of this bulletin was commenced by Richard S. French, Principal of the School for the Blind, in the spring of 1936. Vierling Kersey, then Superintendent of Public Instruction, encouraged Dr. French in this work and planned the publication and distribution of the material by the State Department of Education.

The present Superintendent of Public Instruction is indeed glad to offer this bulletin to the public schools of the state in the sincere belief that it will prove effective in accomplishing the purposes stated by the author in his Preface.

Walter F. Dexter

Superintendent of Public Instruction

PREFACE

This handbook is intended only as an introduction to a series of problems, mostly unsolved. It is not in any way intended as a specific guide, except in a few matters where existing laws or procedures which have been worked out over a period of years justify definite directions. Its main purpose is to create on the part of teachers and others with more or less direct control over visual tasks and the conditions under which they are pursued, a consciousness that there are problems, urgent problems, with regard to lighting, seating arrangements, eye examinations, and special educational provisions in those cases diverging radically from the normal. It is the author's hope that because of this little manual, teachers particularly will look a bit further into underlying causes before condemning a child as stupid, lazy, or what not, when the trouble may well be visual. It is hoped that in the future in California there may be no repetition of the conditions found in one schoolroom in a most enlightened community, where forty children were sacrificed to bad and inadequate lighting because the teacher was protecting her own supersensitive eyes. It is hoped that symptoms will lead to intelligent suspicion of wrong conditions, either in the child or in the environment, and thence to consultations, examinations, and action.

The author has consulted only the most outstanding authorities in each field. In five instances he has directly made use of the materials supplied by contributors who were experts in their respective fields. Wherever possible he has checked and had others check for discrepancies or any signs of inauthenticity or unreliability. Errors have doubtless crept in and both the author and the others responsible for this publication invite calling their attention to such errors by direct communication over the name of the person detecting them. In no case is the committee on publications of the Sight Conservation Council of Northern California to be held responsible either for factual materials or opinions. Each contributor assumes responsibility for his own statements, but not, of course, for his sources.

Some topics which might have been touched upon have been avoided on purpose. Thus the whole question of the responsibility of employers in industrial accidents involving sight has been left to a future compilation in which the proper authorities can participate. Lighting, too, has received only a fraction of the attention which is its due, in the expectation of future contributions. Definitely controversial topics have been avoided as much as possible, though the author

can hardly hope, even with the most cautious wording, to have escaped committing himself on points where the more radical just will find cause for offense. All he can hope in this matter is that he has been too meticulous to have lent himself to unscientific bias or mere casual opinion. The booklet is sent out in the interest especially of school children and not to influence public opinion in favor of any one group or any one practice.

My thanks are due not only to the contributors named and to the State Department of Education in making possible this publication, but to my critics as well for their generosity in reading the copy and making their notes available for important corrections. I am especially indebted to Mr. Earl Terzian for preparing the drawings for all the figures in the text. These were taken from a number of most reliable scientific sources. The frontispiece is from original photographs. Illustration was made possible through the cooperation of the Sight Conservation Council or, more specifically, by its executive committee.

The appendices were added in the interest either of clarity or of further investigation on the part of the readers. The general bibliography is made short because lengthening would mean largely a repetition of the same materials. Books of too technical a nature have been omitted. The average teacher will find sufficiently reliable articles in standard encyclopedias on any special topics that he may want to investigate further. For specific and authentic materials on technical sight conservation he is referred to the publications of the National Society for the Prevention of Blindness, including its excellent quarterly, *The Sight Saving Review.* The technical publications of other national organizations interested in sight conservation and the effective utilization of sight are for the greater part reliable. The reader who wishes to investigate must, of course, use discrimination where such secondary problems as that of salesmanship "enter the picture." Increased sales neither justify nor condemn such a movement as that for sight conservation, though increased sales as a part of richer and more comfortable human living surely can not be held *anathema* just because of commercial connection. Genuine service to humanity and to the progress of science is not incompatible with business success. In trying to find, then, some quotient of reliability in commercial publications one can only apply what are good tests of reliability in other connections and "make up one's own mind" on one's own findings. In no case is human welfare, more particularly child welfare, to be sacrificed to any motive, even the most scientific.

In this connection the writer would like to stress the need of "common ground" for all vitally interested persons. For one group of scientifically trained persons to condemn or to seek to discredit another group is to invite public distrust. In this time of confusion with many

quacks offering panaceas not only must the scientifically trained stand for correct procedure more than ever but men and women of enlightment must stand together in good will and present a solid front both for human welfare and against all evil practices wherever found.

R. S. French

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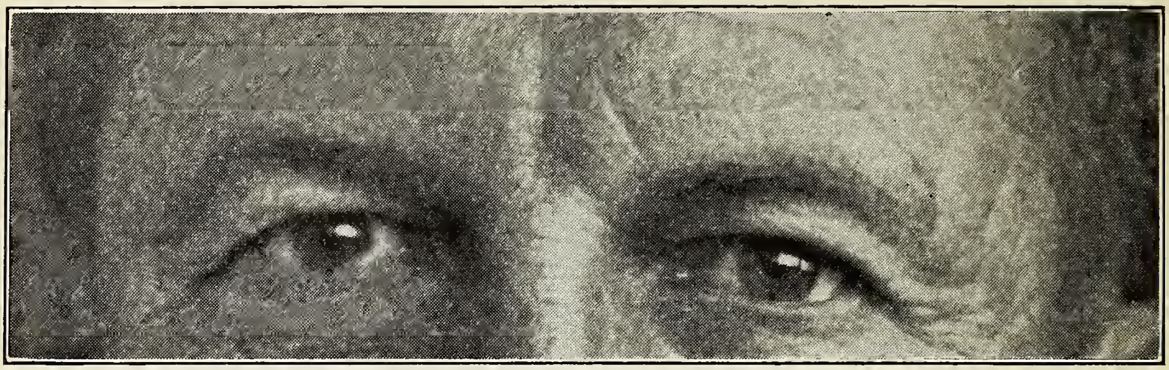
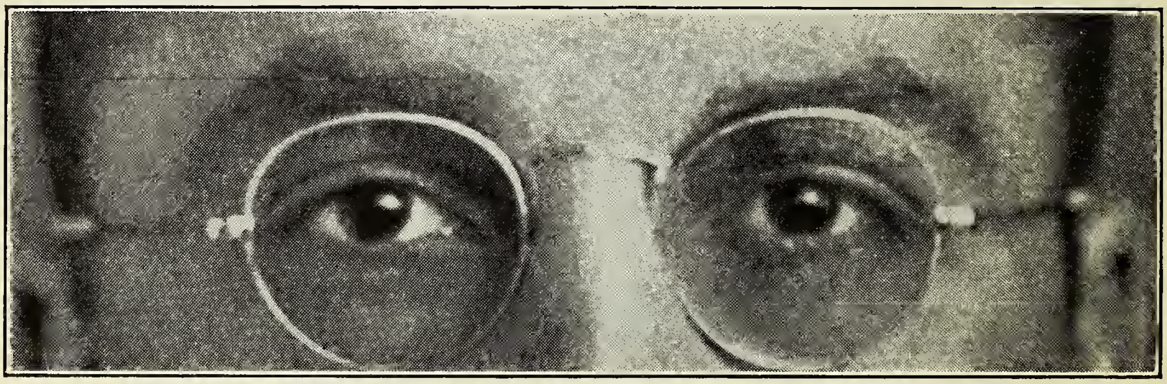


Eyes—Unimpaired



Sight Corrected With Lenses

A Case of Preventable Blindness—Complicatied Conjunctivitis

Section I

VISION, ITS SALIENT CHARACTERISTICS

H. G. Wells, in what is perhaps the profoundest of his short studies of human nature, *The Country of the Blind,* describes an isolated Andean land where for centuries the population had been totally blind. Its manner of life, its morality and its mentality had come to be wholly dominated by tactual, auditory, taste, and smell concepts, with no element of the visual except as a remote tradition. Into this land a man of normal vision almost literally fell. After his first revulsion of shock and astonishment he proceeded to act on the old Spanish proverb "In the country of the blind the one-eyed man is king." He was, however, speedily disillusioned; he was regarded as awkward and ill informed, and his talk of the things of sight was considered insane. As a last humiliation it was proposed to remove his eyes that he might, it was hoped, become "normal" in mentality, character, and actions!

While the setting is imaginative and even its most essential features can never be reproduced in actuality, Mr. Wells' story may serve as a parable for the introduction of the student to the answer to the question "What is vision?" namely that vision has the characteristics of that immediate experience which is called intuition. No one who has no organ of vision, and who has never seen, can know what sight is, even by analogy. One who has had sight and has lost it, does know, and lives largely a life of visual experience because he can still *imagine,* still visualize. Even the perception of light brings enough visual quality into experience to affect mental and emotional development; certain tonal effects in health and in mental alertness are directly traceable to light stimuli. But light phenomena without color and without form are so restricted in their influence that one who has only light vision, though it may keep the visual apparatus alive, can not truly be said to have sight.

With color vision and object vision, sight becomes the most important of the senses, though many defects are still possible, the distortions and imperfections of myopia and astigmatism for instance. One can not deny that the myopic person may, even without the mechanical correction of his defect, be almost wholly visually minded, that is, dominantly visual in all his learning processes and his mental imagery. With an approach toward the perfection of the visual organ in the best human sight, not only does vision dominate the mental life;

it becomes the main factor in arousing, determining the course of, and interpreting the affective life or the life of feeling. Vision is the main element in pride, for instance, in all its manifestations and vagaries. In advertising, the visual appeal is used to arouse hunger, thirst, the longing for comfortable rest, secondary sex instincts, and so on, with some rather startling intermixtures in present-day advertising that only serve to clinch the fact of the dominance of vision.

The percentage of visual impressions in the total sensory experience can not be determined with scientific accuracy. The skin and muscle senses, as well as the obscure internal senses, play a much larger part in the intellectual and emotional life than is usually attributed to them. In any case, sight impressions make up the bulk of the perceptive and imaginative side of mental experience. More important than percentages are the other qualities of visual impression. These in their more practical aspects are location, distance, and direction; clarity and definition; comprehensiveness and integration, with duration; harmony and discord; tonal stimulation; illusion and inference. Each of these requires a brief treatment.

Crile [1] lists three distance ceptors—sight, hearing, and smell. In contrast are the contact ceptors, taste, and the skin senses of heat, cold, pressure, and pain; the kinesthetic or muscle-joint senses; and the senses of the internal viscera. The contact senses of taste and touch make us acquainted with certain aspects of the outer world, roughness, smoothness, salt, sweet, sour, and bitter; the kinesthetic and balance senses give us other vital impressions, weight, resistance, locomotion, buoyancy. The pain sense in general, in contrast to comfort and well-being, warns us of the power of the external world to harm or to destroy. The distance ceptors can not give us any such immediacy of experience because they work through media and the varied stimuli producing impressions through these ceptors are either carried from a distance as chemical effluvia or propagated at a distance as light or sound waves. The contact ceptors and the internal sense mechanisms are in a real way much more vital, much more overwhelming. Hunger, for instance, can shut out practically every other impression and break down all other nerve reaction; so can a gnawing and persistent pain as in certain degenerative diseases. All the contact and internal senses give some impression of location and distance on or within the body, though there is frequent confusion in localization; they give no impression whatever of distance or direction outside of the body except by inference. Smell, though it gives some impression of distance, does so chiefly in connection with sight and hearing. Its importance is

[1] George W. Crile, *Man, an Adaptive Mechanism.* New York: The Macmillan Company, 1916, chapters III and V.

relatively slight in the civilized human being; anyone would think of locating an object by smell only under most unusual circumstances. Hearing similarly has such restrictions with regard to distance, direction, and location, that only totally blind people make much use of hearing in locating objects or inferring directions or distances.

Sight then is preeminently the sense of distance, direction, and location. Perspective, shading, binocular vision and stereoscopic vision all enter into the perception and judgment of distance. Eye movement is also important in gauging the distance between objects. The trained and practiced eye can tell within reasonable limits of precision the length and width of a board, the distance or height of a tower or hill, whether a deer stands in front of a grove or is merged in the undergrowth, whether a ditch can be safely jumped or requires bridging, how many letters will have to be carried over at the end of a line of type. The practiced eye of the savage and the woodsman can do much more under exacting natural conditions than can the unpracticed eye. But equally under city conditions the practiced eye can tell much better than that of the savage or countryman the speed and distance, for instance, of an approaching automobile.

Definition and clarity are even more the exclusive properties of vision. Sound perceptions are always intensive and momentary with quality changes from moment to moment that preclude minute examination and analysis. In fact, strict sound analysis must resort to visual devices, smoked paper on drums for instance, in order that accurate measurements and comparisons may be made. Think of putting down two sounds side by side, placing a ruler on them and testing minuteness of difference! Yet that is exactly what we can do with two visual objects. Visual definition and clarity depend on the mechanism of central vision which will be discussed later. Only by bringing objects into focus can they be subjected to minute scrutiny. The most practiced eye can never test a thing minutely in the peripheral areas.

More important still is the comprehensiveness of sight, and the possibility of bringing things into relationship simultaneously, which, together with duration, renders possible the mental act of integration, the correlation of objects or parts into wholes. Closely related is the act of scaling; that is of reducing or enlarging areas and distances into comprehensible sizes as in maps, models, plots, plans, and other forms of reduced or of magnified representation. Scaling in any comprehensive way is impossible for any other sense than sight, such scaling as is submitted to the blind being at best a rather crude and piecemeal substitution. The various sized maps of North America would be a case in point. The vast mass of survey material which constitutes

the original data of parts is finally brought together in a series of easily grasped miniatures and one has integrated a continent in all its relationships. A sketch, diagram, or model of a microscopic protozoan is a reverse case, where size too small for comprehension is magnified to the point where parts in their relationship stand revealed.

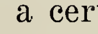
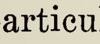
Most vital in the process of integration is the possibility of simultaneous examination. Suppose an orchestra conductor wants to compare two similar scores in order to evolve a third one suited to his purpose. It is inconceivable that he will stand between two orchestras, one playing the one and one the other. He has two choices—he can have the first played and then the second, but he thus subjects himself to the tricks of memory. Or he can put the written scores down side by side and compare them bar by bar and note by note. The second method is visual. He will more likely combine the two and the sound integration will be all the more effective for having a partially visual basis. The duration element in the comparison of visual objects or in the grouping of visual objects is of a very different nature from sound duration—the two written scores do not change under the conductor's glance, but in the actual playing of the piece the flute may be off a note, the orchestra must stop, a section be repeated and the flute corrected with the easy possibility that the cymbals have this time clashed a tenth of a second too late. The point is that in visual comparison and integration, objects and relationships can and usually do stay put. Sounds can not stay put, even in a phonograph record, for purposes of comparison.

Harmony and discord are usually regarded as belonging to sound, but their consideration has an important place in any defining of sight. Harmony has to do not only with color blendings and light shadings but with the principles of contrast as well. Discord is simply the negative of harmony. For genetic reasons most probably certain combinations and blendings of color and certain shadings and contrasts produce pleasing or restful effects, while certain contrasts and certain ensembles produce irritation, restlessness, or even physical pain. Color and light and shade combinations differ in their effects with different individuals and with the same individual from moment to moment. The element of visual fatigue enters to some extent in the time variations. Nothing is more pleasing for a time than a sharp mountain silhouette against a sunset sky, but no one can look longer than a few seconds at such a scene. He can turn back to it after a brief rest with perhaps new elements of delight. Parenthetically, it may be remarked that the esthetics of sight can be very greatly advanced with more extended studies of lighting, of contrast, and of fatigue.

Nothing is more dismal and inharmonious than the average schoolroom. Taste is formed under conditions so distressing that one can not wonder at the applause the writer once heard in a cinema when the burning down of a schoolhouse was shown in the news. The audience was three-fourths school children. Books and pictures and home surroundings almost equally are an offense to sight—studies in what should not be. Collective housing is still more offensive than the family home, and most parks offend eye-harmonies and visual esthetics. For most part, only natural scenes and the highest in art, conform to what should be; natural scenes because the eye has developed in and through them and the highest art because it gets at the heart of nature.

Tonal stimulation is definitely physiological and yet an important part of seeing, especially in the neglected field of attention. The difficulty of sleeping in brightly lighted surroundings illustrates the immediate stimulating effect of light. The continuation of light stimulus undoubtedly helps in keeping up alertness, while variation in stimulus equally prevents a serious lowering of attention. One can be continuously attentive to visual phenomena over a great time and space range largely because of shifting elements and probably partly because of the vital interests involved. This is illustrated in the extreme case by the automobile driver who can "do" ten or more hours steady driving under the duress of need, but he is helped by turns in the road, change of scene, changing light, and so on. If he had one and one only steady visual stimulus throughout, the fatigue would no doubt overcome any possible alertness and attention, and the desire for sleep would become irresistible. Just how long effective attention can be concentrated on a dominantly visual task remains to be shown experimentally. Teachers would do well to give special consideration to this phase of sight and of education.

Illusion has been considered preeminently the defect of sight. Whatever truth there may be in such a vague tenet comes from the dominance and the complexity of vision. The nature of illusion need not be discussed here, except to have it made clear that what are commonly called optical illusions are often really fatigue phenomena as in the case of complementary color illusions, or inference phenomena.

This leads to the last point in the discussion of what sight is, namely to the conclusion that much that goes under the name of vision is really inferred from the repetitions of experience. For instance, we say, "I saw that she was happy." What we really saw was certain colors and shadings in a certain setting. In particular, the curves of the lips were up thus , instead of down . The inference was through muscular contractions originally connected with the tasting of sweet and sour, to the pleasure or pain reactions produced by

mental states of well-being or of maladjustment. Such experiences must have entered the life of the speaker or he could not know the difference between a happy and a sad look. Certain totally blind people make the same type of inferences, but far less accurately, from voices. Motion is likewise an inference from a series of positions held by a given object in relation to others. The ''movies'' take advantage of the disjunct quality of eye-pictures to produce the ''illusion'' of continuous motion. There is really no illusion except in the fact of inference; that is, that we never see motion but only a series of changing positions.

We can define sight, then, only by considering its extreme complexity, the mixture of simple sense elements with the product of long experience, and the working together of the whole mechanism including muscular reaction, appetites, desires, and the acts of intellection, and the blending of the elements into the whole of conscious life. Any other definition would be so restrictive as to be meaningless.

Section II

THE VISUAL ORGAN

In this section there will be no sharp distinction between structure and function. Too much scholastic classification has entered into consideration of the visual apparatus. A functionless structure is no longer an eye, though dissected eyes and eye models help understanding if we remember that they are dissections or models. The only true visual apparatus is the living, functioning eye with all its appendages and connections.

The eye consists of the eyeball, certain muscles which move it, and the lachrymal apparatus which keeps the front of it moist. The moistening is a part of seeing as a dry eye would at once give blurred impressions; hence the film of liquid over the front of the eye is really a part of the structure. The eyeball is contained in the front of a bony orbit and is roughly spherical, with an average diameter of about an inch (24 mm). From the front of the larger sphere a segment of a smaller sphere projects slightly forming the cornea. The eyeball has three coats, an external or protective coat, a middle (largely vascular) coat and the interal or sensory coat. There are three refracting media; in succession, the aqueous humor or fluid, the lens, and the vitreous humor or body.

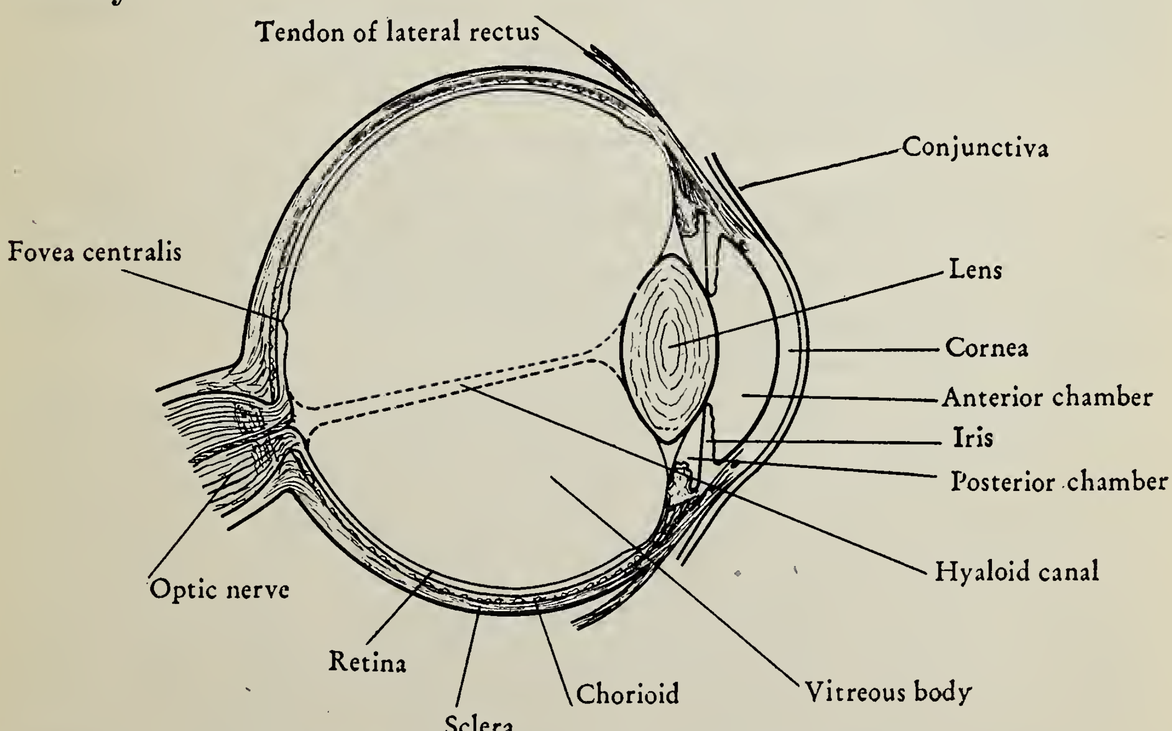


Figure 1. Cross-section of the Human Eye

The major portion of the eyeball is protected by the tough, sclerotic coat, called the white of the eye, really yellowish in most races, while the cornea covers the anterior one-sixth. Most of the sclerotic is hidden by the orbital structure and the eyelids while the cornea is wholly exposed in the open eye. The cornea is continuous with the sclerotic but is more convex. The cornea consists of five layers, the outermost of which is stratified epithelium. Its almost perfect transparency is due to structure and to the fact that all five coats have the same refractive index.

The middle or vascular coat of the eyeball consists of the choroid, the ciliary processes and the iris. The choroid does not come forward quite to the junction of the sclera and cornea. It is rich in blood vessels and contains many pigment cells all bound together by connective tissue.

The ciliary processes are some seventy triangular ridges, radially arranged, with the apices toward the rear of the eye, and their bases level with the corneoscleral junction. They are vascular like the rest of the choroid and contain in their interior the ciliary muscles which consist of both radiating and circular fibres. The radiating fibres pull forward the chorioid when they contract. The circular fibres lie inside the sheath of radiating fibres and are few or lacking in short-sighted people.

The iris is in many respects the most remarkable structure of the eye. It is usually colored, giving the characteristic gray, brown, black, and so on of the eye colors. Blue color is due to the blackish pigment to the rear of the iris showing through. In pure albinism the iris is pinkish. A contractile diaphragm, it may close almost to a pin point or many open to uncover the lens almost entirely. The control is due to circular muscular fibres and either muscular or elastic radiating fibres. The total mechanism regulates the amount of light admitted to the interior of the eye and in the healthy normal eye responds automatically with a quickness and a precision which is one of the greatest wonders of the human mechanism.

The inner or sensory layer of the wall of the eyeball is the retina. It is an exceedingly delicate transparent membrane lining most of the interior of the eye up almost to the sclerotic junction with the cornea. It grows thinner as it approaches the front of the eye. A short distance behind the ciliary processes, the nerve part of the retina stops, forming a scalloped border called the *ora serrata*. Microscopically examined, the retina, in its posterior parts is seen to consist of eight layers from front to back consisting of (1) nerve fibre; (2) ganglion cells; (3) inner molecular layers; (4) inner nuclear layers; (5) outer molecular layer, much thinner than (3); (6) outer nuclear layer; (7) "rods and

cones"; and (8) pigment. Unsupported, the delicate nerve structure of the retina would collapse; this is prevented by a supportive series of radial fibres of connective tissue known as the fibres of Müller.

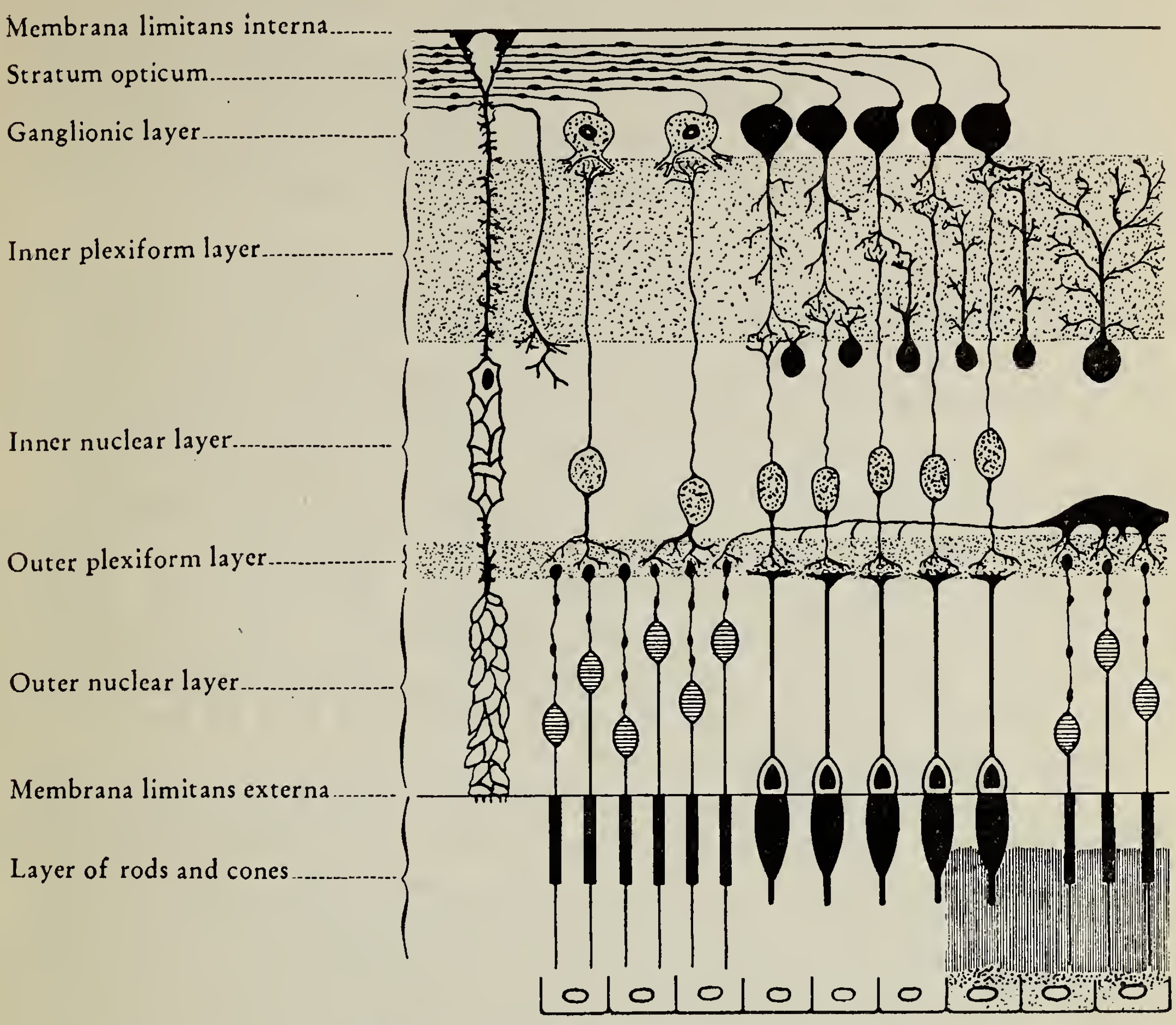


Figure. 2 Layers of the Retina

When one looks at the retina from the front with the "naked eye", he notes two small marks on it. One of these is an oval depression about 3 mm across which is pigmented with yellow and hence known as the yellow spot or *macula lutea*. This depression is situated almost in line with the central axis of the eyeball. At its margin the nerve fibre layer is thinned and the ganglionic layer thickened. But at the center both these layers disappear and in the rod and cone layer only the cones are present. This remarkable structure, characteristic of the primate eye, is the region of greatest visual acuity and renders possible the minute visual scrutiny which marks close examination in the human being. The region of absence of rods and point of maximum visual acuity is called the *fovea centralis*. Macular or central vision, in contrast to peripheral, will be discussed later (Section III).

The second spot on the retina is slightly below and toward the inner side of the yellow spot. It is a circular disk, with raised margins

and depressed center and is called the optic disk. In structure it contrasts completely with the yellow spot, for all layers except that of nerve fibres are lacking and consequently there is no sight in this spot. It is therefore commonly called the blind spot. It is the point of entry of the nerve bundle known as the optic nerve, the largest of the cranial nerve strands. At the center of the blind spot the retinal artery enters and divides into branches. Careful examination of these rear structures in the living eye was made possible by the invention of the ophthalmoscope.

The crystalline lens, with its ligaments, separates the aqueous from the vitreous chamber of the eye. The lens is double convex but the posterior surface is more curved than the anterior. Radiating from the anterior and posterior poles are three faint lines forming a Y, the posterior Y being erect and the anterior inverted. Running from these figures are lamellae, like the layers of an onion, each made up of fibres called the lens fibres. It is thus seen that the lens is not an amorphous mass but a highly complex structure. It is enclosed in an elastic, structureless membraneous sac. As in the case of the cornea, the almost perfect transparency of the lens is due in the first instance to its remarkable substance and in the second, to the fact that all layers have the same refractive index.

The ligament of the lens is the thickened forward part of the membrane (hyaloid) which surrounds the vitreous body. This ligament is closely connected with the iris at the *ora serrata,* then splits into two layers of which the anterior is the thicker and blends with the capsule of the lens. When its attachment to the *ora serrata* is drawn forward by the ciliary muscle, the lens by its own elasticity increases in convexity. This constitutes the mechanism of distance accommodation. Between the anterior and posterior splitting of the hyaloid is a circular lymph space surrounding the margin of the iris. This is the canal of Petit.

The aqueous humor, contained between the lens and its ligament in the back and the cornea in front, is really a weak solution of common salt. The space containing it is unequally divided into a large anterior and small posterior chamber by the perforated diaphragm of the iris.

The vitreous body or humor is a rather thick jelly which fills all of the interior of the eyeball back of the lens. It is surrounded by the hyaloid membrane and is concave toward the lens, which fits into this concavity. The composition of the vitreous is nearly the same as that of the aqueous body. Its transparency in the normal healthy eye is as nearly perfect as is possible to organic growths.

The arteries of the eye are not a part of seeing. Their function is nutritional only and so long as they work normally they present no

feature of special interest. Likewise the veins and lymph vessels play no seeing part but simply take away the blood supplied by the arteries and act as scavengers to the tissues of the eye.

Accessory Structures

The accessory structures of the eye are protective, lubricative, and adjustive. To the first group belong the eyebrows, the eyelids with their fringe of hair, the conjunctiva and the bony structure of the orbit, together with its softer and cushioning tissues. To the second, belong several sets of glands, of which the lachrymal are the largest and most important, the ducts of the glands and the large duct and collective tubes which drain the tears from the eye into the nasal passage. To the third, belong the seven muscles which produce the eye movements and bring about binocular coordination.

In most higher animals the lids can completely cover the eye. They not only offer the greatest protection against dust, flying objects, and excessive light, but by their frequent involuntary closures spread moisture over the front surface of the eyeball and cleanse and lubricate it at the same time. The nictitating membrane present in birds effects the lubricating and cleansing function without the closure of the lids. The conjunctiva is a layer of mucous membrane which lines the back of the eyelids and is reflected onto the front of the globe. On the front of the cornea the conjunctiva is continuous with the outermost layer, that of epithelial cells.

Of the three sets of lubricating glands, the lachrymal are by far the largest and most important. They secrete tears, normally at the same rate that they are taken up by the nasal duct. Tears are nearly pure water, but with common salt and other compounds that make them soothing to the outer surface of the eye and to the eyelids and at the same time smooth those surfaces. Pure water is slightly irritating on the same surfaces. Emotional or other stimulation causes an excess production of tears and an overflow over the lower eyelid.

The muscles of the eyes must be considered in pairs as belonging to both eyes. Of the seven muscles, six rise close to the optic foramen. The *levator palpebrae superioris* is the highest and passes forward to the superior tarsal plate and fornix of the conjunctiva. The *superior* and *inferior recti* are inserted into the upper and lower surfaces of the eyeball respectively; they make the eye look inward as well as up and down. The external and internal recti are inserted into the sides of the eyeball and make it turn outward as well as inward. The superior oblique, the most remarkable eye muscle, runs forward to a pulley in the inner and front part of the roof of the orbit, round which it turns to be inserted into the outer and back part of the eyeball. It turns the glance outward and downward. The inferior oblique rises from the

inner and front part of the floor of the orbit and is also inserted into the outer and back part of the eyeball. It directs the glance upward and outward. These muscles are supplied by the cranial nerves in pairs, the superior oblique by the fourth, the external rectus by the sixth and the rest by the third.

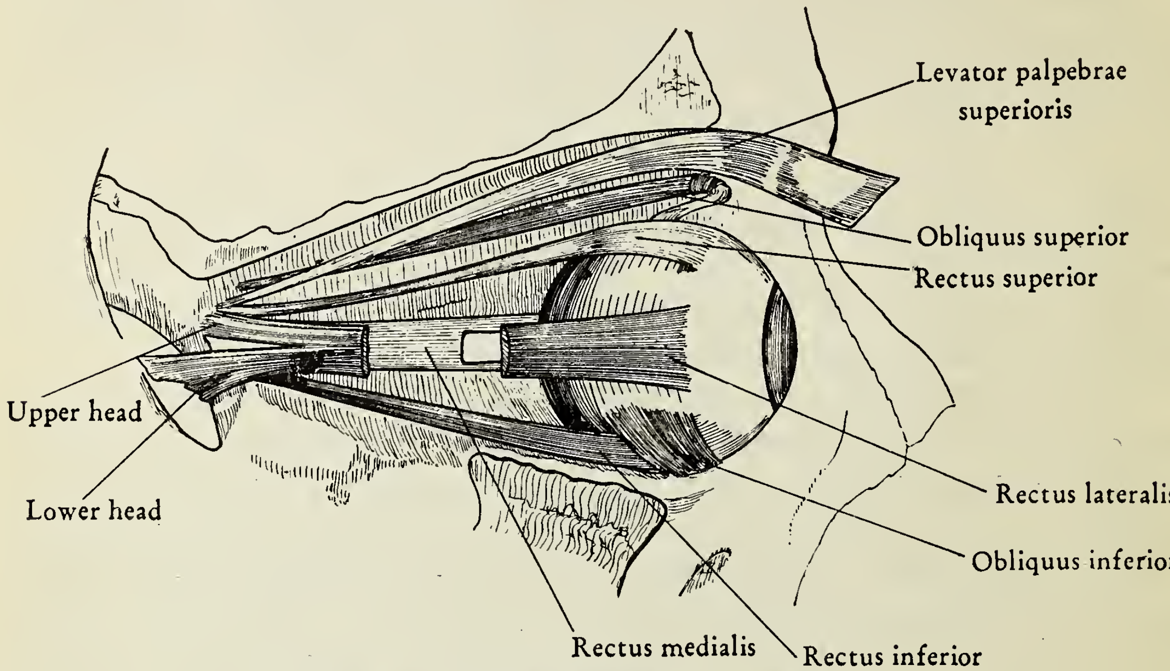


Figure 3. The Muscles of the Eye

The coordinate innervation of the muscular sets of the two eyes is a strikingly precise and generally automatic mechanism. It should be kept in mind that to glance with both eyes to the left, for instance, requires opposite action in the one eye from that in the other. Faulty musculature and incoordinate or spasmodic innervation lead to the pathlogical phenomena of strabismus, nystagmus, and so on. The insistence of certain groups on the examination and treatment of the eyes as a pair is justifiable in the average case of human sight. Where one eye is functionless usually if the eyeball is left in place the coordinations continue as if the eye were normal.

The optic nerve leads through the optic chiasma, an X-shaped partial crossing of the nerve fibres to the brain where it branches, the main part going to the visual centers of the occipital lobe. Figure 4 shows something of the complexity of the nerve connections and terminations and more particularly that the partial crossing in the optic chiasma results in keeping nerves from the right half of each retina in the right hemisphere of the brain and nerves from the left half of the retina in the left hemisphere of the brain.

Just what happens when impluses from the retina "register" in the cerebral cortex, we do not as yet know. The complexity and indirectness of the mechanism of vision lead to the certain conclusion that vision is an interpretation of the outer world. Whether or not

what we see corresponds to reality is a question in philosophy. The pragmatic test requires only that what we see or what we think we see shall correspond sufficiently with the rest of experience to make for effective action in any given case. When an action dependent in any degree on vision is ineffective, we are likely to blame the visual mechanism as imperfect; however even the simplest situation in appearance involves such complexity that one must go beyond the visual part to determine whether or not sight was at fault. A case in point would be missing the mark in firing at a moving object, say a deer. Sight might be at fault, or the "sights" not properly adjusted, or the discharge delayed or advanced, or the deer may have accelerated his motion at the moment of firing and so on. In any case, the one missing the mark will blame something, anything, except himself!

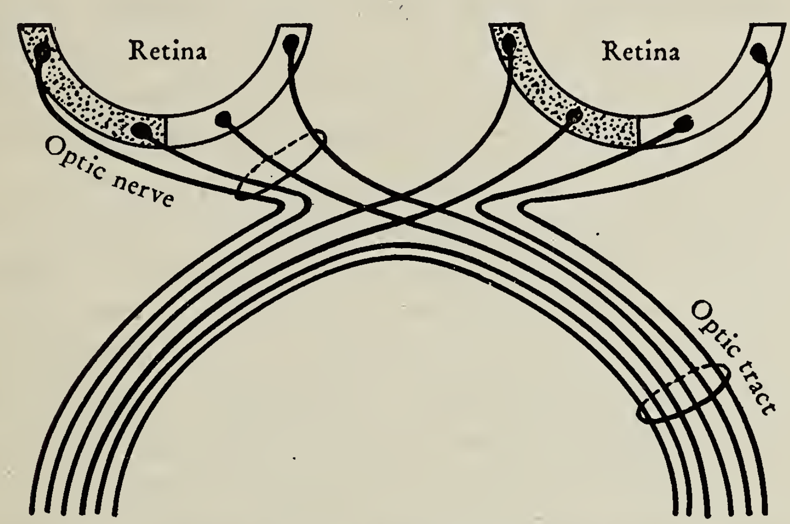


Figure 4. The Optic Chiasma

Section III

THE DEVELOPMENT OF THE EYE— EMBRYOLOGY AND EVOLUTION

Diagrams will have to tell most of the story of the development of the eye, as a description in words is likely to lose the student in a labyrinth of technical terms. Those who haven't forgotten all their fundamental biology will recall that in higher animal structures the whole complex body is derived by modification of structure, along with specialization of function, from three primitive layers—the ectoderm or outside layer, the mesoderm or middle layer, and the endoderm or inside layer. These in turn are derived by the multiplication of the single original cell into a mulberry-like mass, the invagination of a part of that mass to form an inside and the formation between the outside and inside layers of the complex mesoderm. They will recall still further that from the ectoderm are derived not only the skin structures but the nerves as well. By one of those processes in which nature seems to delight, the nerves from being *outside,* infold and proliferate until they become the most *inside* of all body parts in the case of the brain and spinal cord, and the sympathetic system. As the endoderm does not enter into eye structure or eye-brain connections, we have only to add that the eye is derived fundamentally from the superficial ectoderm (essentially the skin) and the

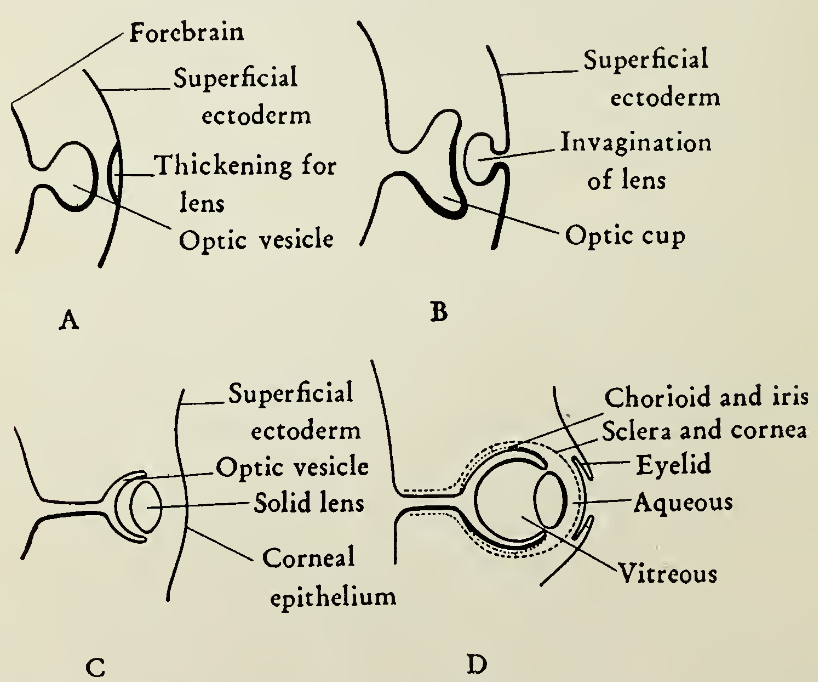


Figure 5. Stages in the Development of the Human Eye

now enclosed ectoderm of the brain and nervous system, with the mesoderm acting as intermediary and supplying the missing parts. The story of the origins, growth timing, and fitting together of the complex eye structures into a harmonious unity is perhaps the most fascinating story of embryology.

The sensory part of the eye starts with a globule projecting from the forebrain. This is the *optic vesicle.* The nearest part of the brain becomes restricted and elongated to form the optic stalk. *At the same time* the ectoderm covering the sides of the head becomes invaginated after a decided thickening over two comparatively large areas. The thickening continues and at length this bit of superficial ectoderm breaks all connection with the exterior and becomes a flattened body, the future lens, toward which the optic vesicle projects. The vesicle itself cups to receive the lens, ultimately almost touching the lens at its thin edge. The cells of the vesicle are gradually transformed, the outer ones forming the retinal pigment and the inner ones making up the seven layers of the retina proper. The invagination of the optic cup extends, as the choroidal fissure, along the lower and back part of the optic stalk, and into this slit some of the surrounding mesoderm sinks to form the vitreous body. When this has happened the fissure closes up.

The anterior epithelium of the lens vesicle remains unchanged but from the posterior the lens fibres are developed and gradually fill the whole cavity. The superficial layer of head ectoderm, from which the lens was originally invaginated and from which it has become separated, changes to the anterior epithelium of the cornea, and between it and the lens the mesoderm sinks to form the main part of the cornea, the iris, and the anterior chamber of the eye, while surrounding the optic cup the mesoderm forms the sclerotic and choroid coats.

Up to the seventh month in the human fetus the pupil is closed by the *membrana pupillaris,* derived from the capsule of the lens which is a part of the mesodermal ingrowth.

Most of the fibres of the optic nerve are centripetal in origin; i.e., they derive from the ganglionic cells of the retina as axons. Some of the nerves are, however, centrifugal, i.e., they come from the nerve cells of the brain.

The eyelids are developed as ectodermal folds which grow together about the third month of development and are not again separated in man until a short time before birth. In some of the mammals the final separation of the lids takes place after birth. The lachrymal sac and duct are formed by solid ectodermal thickenings which are later pierced by canals.

We thus see that the optic nerve and retina are formed from brain ectoderm; the lens, the anterior epithelium of the cornea, the skin of the eyelids, conjunctive and lachrymal apparatus from the superficial ectoderm; while the sclerotic and choroid and the vitreous and aqueous humors, as well as the iris and cornea are derived from the mesoderm. Any failure in the timing of these growths would result in a defective or monstrous condition of the completely formed eyes. The mechanism of synchronization is not yet understood but is assumed to be a part of prenatal metabolism, with the "chemical messengers" playing a major part. When we consider any of the thousands of things that might happen to delay or pervert the course of the various growths the wonder is that in an organ of such complex and varied origins we can have any unity of structure and of function.

Response to light in both plants and animals is as old as organic nature. Both one-celled protozoans and algae are so constituted that they make perfectly definite responses to light stimuli. Algae being dependent on light for photosynthesis must avoid places where light does not penetrate for long periods of time. Under such conditions they either perish or go into a resting stage. Floating types tend to concentrate near the surface where they have a maximum of light. Response to light, however, is not sight, and we can conceive of sight as being developed only in response to growing needs due to organic complexity and complexity of environment, the two combining to render behavior too complex for the organism to get along by tactual and internal responses alone. *Sight does not develop as such until understanding things at a distance becomes essential to the life and activity of the organism.*

The two simplest forms of response to light are phototropism or turning to the light and photophobism or shunning of the light. Both are illustrated beautifully in certain plant responses. The sunflower is only an extreme case of what all plant structures with green or chlorophyll bearing parts must do to survive, that is, bring the green parts into the light to the greatest extent possible. The growth of the "air-roots" away from the light toward a damp wall, for instance, shows the negative side of light response. In the case of phototropism the modification of epithelial cells to produce a greater concentration of light in the leaves of many higher plants may indicate a specialization in a direction that could easily lead to a secondary development in the mechanism of response. It is doubtful, however, if sight is a by-product of mere phototropism. It is more likely that the first eye-spots develop to give an awareness of light as light and not as the agent of photosynthesis. Only a very few animal forms

carry on photosynthesis and so far as we know true plants never develop eye spots.

The first development toward an eye in the animal series comes with a thickening of epithelial cells in spots over areas of exposure to light, and the supplying of the lower ends of these cells with pigment and nerve connections. The cells are elongated like the palisade cells in green leaves. Why they occur in spots probably is for the same reason that freckles occur in spots. The essential features are thickening by elongation, a clearing of the outer surface and conducting media, pigmentation at the base, and nerve connection. This gives a greater awareness of light over restricted areas, for instance along the back in certain worms. The tendency of the spots to form near ganglia is very definite and their special formation and enlargement near the largest, the anterior, that is to say *the head,* ganglia is very significant. Such a spot is shown as A in Figure 6. The series A to F in this figure is diagrammatic and in part hypothetical but represents in the rough what has happened in the development of the invertebrate eye.

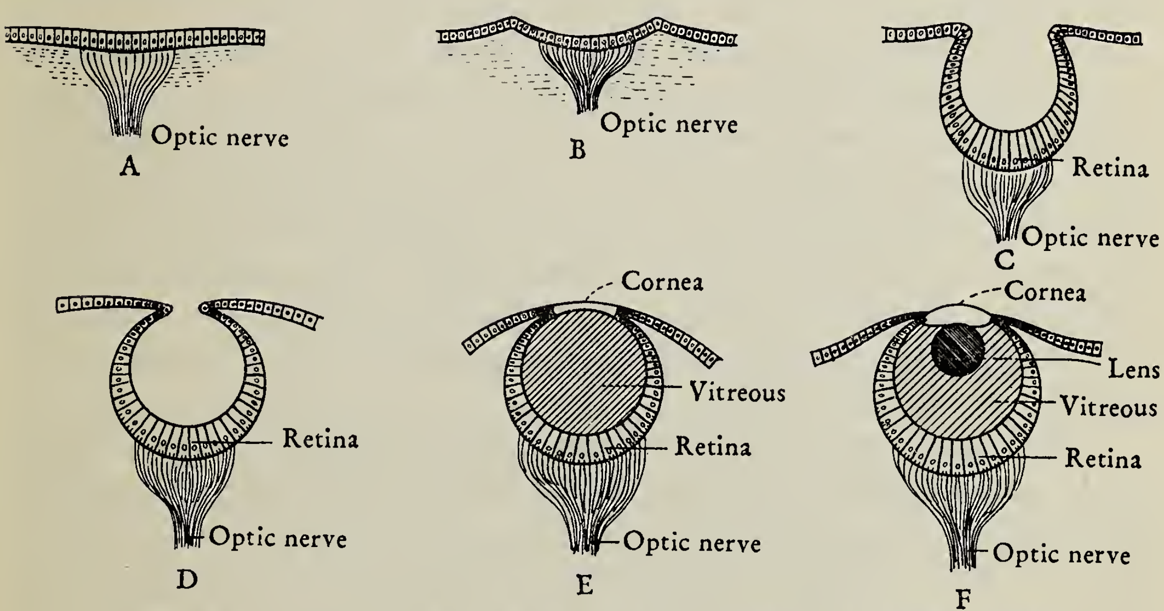


Figure 6. Evolutionary Development of the Invertebrate Eye

The second step beyond the simple eye spot is shown by B. This condition is found in the solen, a headless mollusk with saucer-shaped eye-spots strung all around the edge of the mantle. Next the depression becomes deeper or cup-shaped and the rim higher as in C. This advance is found in the limpet (*Patella*). This structure not only offers protection to the sensitized spot but increases the impression by reverberation within the hollow. The eye-spots in *Patella* are on the *head.*

A definite or true eye is reached in *Nautilus.* This is shown by D. The raised margin has developed so far that its lips have closed to

a pinhole. The sensitized cells have nearly completed the lining of a hollow sphere, i.e., they have practically become a retina. The image formed on the retina will be that of a *camera obscura,* with the difference of course that the retina is rounded. The imperfection of such an image is obvious, and objects seen will be blurred and the guidance offered by such an organ can be at best only very general and crude.

The next step (E) again occurs in Mollusca. A vitreous body has been intruded into the cavity and the opening has been closed with a corneal intrusion. The eye of the *Trochus* and of many other gasteropods is of this type. Some regard the filling of the cavity as a lens, since it is refractive and therefore gives a lens image far clearer and more nearly perfect than would be possible to D. In the squid and other cephalopods the final step is taken in the development of the simple invertebrate eye. Not only is a true lens introduced but the combination of parts (F) gives a compound lens-image as in the vertebrate eye. With this development the eye in the subvertebrate groups ceased its evolution; probably under the conditions of existence of squids, devilfishes, etc., a more nearly perfect eye would have little added utility.

In proof of the essential correctness of the series of illustrations it may be stated that the embryonic development of the eye of the squid follows the steps A to F. First, an eye-spot appears, then it becomes depressed with a raised rim. Next the concavity increases as the rim closes to a pinhole. Then the opening closes and the hollow becomes a vesicle filled with a vitreous jelly. Last of all a cuticular (epithelial) growth from the central point of the surface forms the true lens and a cornea-like structure closes the opening. Only an iris and lids remain to be added.

The compound eye represents an entirely different kind of venture on the part of Nature or Creative Evolution or whatever else ventures into organic experimentation. The compound eye is found only in Insecta and closely related groups and is off the main evolutionary line. What insects see and how they see must remain an eternal puzzle to the vertebrate brain of man. We can only guess; use diagrams and analogy. But we can know that flies and wasps, grasshoppers and their kindred see reasonably well for their purposes. At least their visual responses are reasonably quick and accurate. The inadequacy of the compound eye is virtually admitted, however, by the supplemental use of simple eyes as in the grasshopper. The best that can be said of the large compound eyes of insects is that they give a great range of vision.

From the diagrams and descriptions of the simple invertebrate eye it will be seen that it differs in very fundamental aspects from the eye of man (See Figure 1) and from that of all vertebrates.

1. In the invertebrate eye the nerve fibres terminate directly in the *inner* ends of the nerve terminals or retinal rods, and the farther ends of these rods look *forward and outward* to receive the light. This is thoroughly logical, in fact just what one would expect, and is true of the nerve terminals in all other senses in all animals. *But* in man and in all vertebrates the fibres of the optic nerve *turn back* on themselves and terminate in the *outer* ends of the rods and cones, and the extreme ends of these latter look *backward and inward.* This, be it emphasized, is wholly exceptional among nerve terminals.

2. It is seen that in invertebrates the *whole eye,* both retina and lens, both receiving plate and image-making instrument, is made from the epidermal epithelium. But we have already seen that in man (and in all the vertebrates) the eye is formed partly by an infolding of the dermal epithelium and partly by an outgrowth of the brain to meet these structures, the retina in all its parts and connections being essentially an outgrowth from the brain. This process is not, however, so different as would seem at first sight when it is remembered that both dermal epithelium and brain derive from the primitive ectodermal layer. In ultimate derivation, therefore, both invertebrate and vertebrate eyes come from the same primitive layer, with supplemental structures in the vertebrate eye, proliferating or infiltrating from the mesoderm, in either case marvels of structural growth and complexity.

Various explanations have been given to show how the more complex and effective vertebrate eye grew from the simpler invertebrate eye. No explanation is satisfactory. We merely have to rest back on the facts. The most plausible of the older theories is that of Beraneck,[1] to the effect that the whole invertebrate eye is represented by the lens only in the vertebrate eye; that the retina of the vertebrate eye came about from a stimulation of the brain and is an added structure, the older retina and other truly dermal parts being absorbed in the new lens, or lost. At any rate the vertebrate eye is what it is and as such has further evolved through a long series of changes.

In the lowest class of vertebrates, the fishes, the eye, though formed on a different plan, is probably no better than that of the squids. In fishes the eyes are placed well on the sides of the head, with their axes so widely divergent that the fields of view overlap only to a very limited extent. There is no coordination of movement—each eye looks for itself. There is therefore no common point of sight and no corresponding of points on the two retinae. This precludes binocular vision and hence accurate judgment of solid form and fair estimates of relative distance, based on binocular perspective.

[1] Archives des Sciences Physiques et Naturelles. Geneva, Switzerland, 1890. Third Period, Volume XXIV (July 15, 1890), 361.

Of the vision of amphibians and reptiles we know very little. Of birds we do know that while their optic axes are still widely divergent by a unique arrangement of corresponding points about a very excentral fovea, binocular vision becomes possible to them. Their most perfect vision is still, however, monocular. Birds are a highly specialized class of vertebrates. This seems to hold true of their vision. Avian vision would seem to be carried to its highest degree of perfection in the carnivorous group, especially the high flying hawks, buzzards, and eagles.

In mammals the eyes are brought more and more to the front, the optic axes more and more nearly parallel in a passive state, the convergence of the axes on a point of sight becomes more and more easy; and with these comes the gradual development of corresponding points about a more highly organized *central area,* and hence all the phenomena of a highly developed binocular vision and the precise judgments based thereon. But in mammals in general *attentive observation and accurate preception* of details at the central point of sight are sacrificed to the greater advantages of almost equal vision over a very wide field (or fields). This is particularly true of grazing animals, the horse being most notable in this respect. The sight of most mammals is no doubt keen, perhaps keener than that of the *primates,* in the *detection* of objects; but the primate group, and Man most of all, no doubt excels in *determining the character* of the objects detected.

Only in the higher apes do we find the eyes brought fairly to the front with the axes parallel in a passive state. Only in them do we find the highly organized *macula lutea* with its central fovea, making vision far more clear and accurate at the point of sight. Even a casual watching of the great apes will show that they do essentially human things with their eyes. They bring objects close with their hands, examine them minutely, turn them over, test them in various ways and probably reach conclusions. They don't talk about their findings, however, or record their data!

In man, then, as the last in a long series, we find *thoughtful attention* to the object looked at, coupled with a unique power of the exclusion of other and distracting factors, (one should recall Kipling's Bandarlog at this point and perhaps reread the Jungle Books). Only with such exclusive and abstracting intelligence is constructive thought possible. The existence of the *macula lutea* and especially the *fovea centralis* is necessary to the concentration of attention on the thing looked at. How could the horse with his four fields of vision attend strictly to one object and concentrate his equine attention upon it? How could the dog with his generalized visual fields give close mental attention? He calls in his nose for any close kind of observation and

loses interest with the failure of olfactory response. How could any other animal than man attend strictly to the close and prolonged examination of one object or the equally close and prolonged comparison of different objects? Yet some are willing to sacrifice this Divine difference to a touch of mascara, a drink of intoxicant, a careless speed-mania or to remediable defect, bad print, or bad lighting. Man scarcely deserves to be the end of a long evolutionary series in brain and sight, yet it is probably true that he alone of Creation can concentrate sufficiently to do effective thought-work. The mind's eye, too, must be macular, must have its *fovea centralis,* or we do no effective work. The mind's eye must also be binocular or we get no true perspective either of men or of morals.

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Section IV

LIGHT

It is characteristic of human thinking and interests that we know least about things most intimate and ever present. This is true of light. To venture into its study physically one must be equipped with a very complete and subtle mathematics and a whole armory of instruments of precision. When he has studied most deeply and widely and expressed himself in differentiations, integrations, constants, and what not, he still has not told the man on the street what light is. Perhaps the man on the street cannot know what light is, but he does know if you are standing in his light and he does know that it gets dark when the light goes out. He thus at least knows that light travels in approximately straight lines and can be intercepted and that it comes from luminous objects, light producers, or light reflectors. If a bit better informed, he will know that light comes originally only from highly heated objects, with few exceptions (the firefly, glowworm, phosphorescent substances), and that these objects send out waves or rhythmic disturbances which are like radio waves but much shorter, and bear some analogy to the ripples on water surfaces and some to sound vibrations. He knows in a general way that light waves are exceeedingly short and take an almost infinitesimal period of time in propagation. He may not know that the duration of a wave in the middle of the spectrum bears the same relation to a second of duration as the second does to twenty million years!

Light waves range in length from .38 to .76 microns, a micron being one one-thousandth of a millimeter. Radio waves are more than 100 million times as long, namely, from 5 to 25,000 meters. Heated bodies send out waves that are less than .38 microns in length. These are the waves of frequency *beyond* that of the visible violet, hence ultra-violet waves. They also send out waves more than .76 microns in length, or infra-red waves, that is, waves of frequency *below* that of the red of the visible spectrum. Neither ultra-violet nor infra-red waves produce any visual effect on the human retina or probably on any vertebrate retina. However, these non-visible waves do produce chemical or physical changes which may become visible, as in a photographic plate sensitized specially to longer-than-light waves or shorter-than-light waves. When a light wave enters the human eye and passes to the retina it somehow affects a part of the myriads of rod and cone structures and sends on to the brain a definite impression of red, yellow,

blue, or whatever the wave length, or combined wave lengths, produces in the way of vision. *Light may, therefore, be defined as that form of radiant energy or wave movement within the range of wave lengths, or frequencies, that affects the nerve terminals of the retina in such a way as to produce the sensation called vision.*

Without light the most perfect eye is totally blind. But equally, given light and the eye, what we see and how we see depends both on the original propagation and modification of the one, and the perfection and physiological condition of the other. Thus, sunlight contains a mixture of wave lengths. Falling upon a certain wall, it loses all but a single one or limited numbers of these by absorption. Thus, the wall may look yellow or brown to the observer. If, however, the observer is color-blind, he will not see the wall as yellow or brown, but as gray. It is important to realize, then, that seeing is a partnership, a literally vital partnership, between light and the organ of vision. It is useless to debate whether there would be color or other visual phenomena without the presence of eyes. The physical causes would no doubt be present. Practically the visual part of the partnership is largely interpretation and therefore there could be no beauty, no light and shade *effect* without the presence of the seeing eye and the comprehending brain back of it. From the purely physical point of view light is a segment in a series of vibrations of an ether or changes of field or whatever else it *may be really or ultimately,* a narrow segment with ultraviolet, X-rays, and cosmic rays beyond in one direction and heat waves, radio waves and others in the opposite direction. It is a part of the vast field of electromagnetic phenomena which may cover (and conceal) the secrets of being, of life itself. We are easily drawn into speculation as to whether hypothetical senses might not take in other segments in forms that intrigue the fancy. Might it be possible that there is a radio sense, an X-ray sense, a cosmic ray sense? and so on. We do feel heat, and electric discharges shock us, but the fact remains that most of our knowledge of the world comes to us only on the wings of light. What the antennae of some insects may do or whether sixth or seventh or other senses may exist or what produces a hunch is mostly idle speculation—the solid facts of human perception and consciousness are tied indissolubly to the phenomena of light.

Thus objects seen and not touched are only light coming from different directions and variously modified by absorption and refraction. Touch and kinesthetic experience check inferences as to weight, texture, and the like. We sometimes feel that we do not really *know* until we get our hands on an object. Yet in the vast majority of experiences we are content with what the light-sight partnership gives. Thus we readily dive into water that *looks* deep, we bite into the apple

that *looks* ripe, we withdraw from the buzzsaw that *looks* dangerous. The water *seen* is only light, the apple *seen* is only light, the whirling implement *seen* is only light. Because of the phenomenon of refraction we frequently cannot know whether an object is where it appears to be. We see the sun after it has really set, we must strike in the place where the fish *isn't* if we would surely spear him under water, and men have been known to travel on and on in thirst to the river that was surely only a few miles away but was never really there at all. Similarly, reflection both reveals and plays a Tantalus part. *What then is a seen object? Without other than visual experience it is only light variously modified or the absence of light.*

Visibility varies with a number of factors: the wave length or lengths, the brightness and the total volume of light from a given source, the nature of the media through which it passes, and the location, texture, and regularity or irregularity of the surfaces from which it may be reflected. Each of these will be discussed briefly in the above order.

We have already seen that a light wave may be as little as .38 microns in length and as much as .75 microns. This is another way of saying that as few as approximately 400,000,000,000,000 may be propagated by a luminous object in one second, in which case it will give out only red rays, or as many as approximately 800,000,000,000,000 may be given out in one second and violet light produced. Or various wave lengths may be mixed, producing impure color effects, including white light. If a very limited range of wave lengths is given out, as in the case of the yellow of the sodium gas arc, only the one color can actually be seen. If the sodium light falls on white surfaces, they look yellow; yellow surfaces look still more yellow; and surfaces that absorb yellow look black or nearly so. The case would be similar if a pure green light were given out. In actual practice or actual experience, however, pure colored light is rare and very difficult to obtain. Most light is mixed; white, yellowish-white, as in the case of the sun, bluish-white, violet-white, and so on. The result is that eyes evolved under conditions of impure light sources do not take readily to pure colored light from any source. Such light may be used successfully for special purposes but is not to be recommended for general use.

Brightness usually means the intensity of light as it strikes the retina of the observer. It is dependent, of course, on the number of light units given out by a single unit of luminous surface in a given unit of time. That is, the more light units given off by, let us say, one square centimeter of the surface of any star in one second of time the brighter the star. Practically, brightness is rated differently with different colors, increasing or decreasing distances, and variations in

size and angle of surface. Thus, a red star seems less bright than a white star, or a violet star less bright than a yellow star; a far away star of equal luminosity rates less bright than a near star, though we are inclined to distinguish between bright little stars and dull big stars; surfaces throwing their light off so that only a small fraction comes our way are rated unconsciously as less bright, though we may know by measurement that they are actually brighter than objects shining directly at us. Thus, brightness for common purposes of conscious reaction does not conform exactly to its physical definition: we confuse brightness and total luminosity, brightness and nearness, brightness and directness. And it is true that a small weak light near at hand will produce more lighting effect or visibility than a very large, very bright object at distances measurable only in light years. A small single candle a foot from the printed page will enable one to read, but nobody can read by the light of brilliant Sirius, many light-years away. Thus, illumination, and hence visibility, depends on the brightness, total luminosity, and nearness of the source of light. It depends, too, on whether the light comes directly from its source or is variously modified on its way.

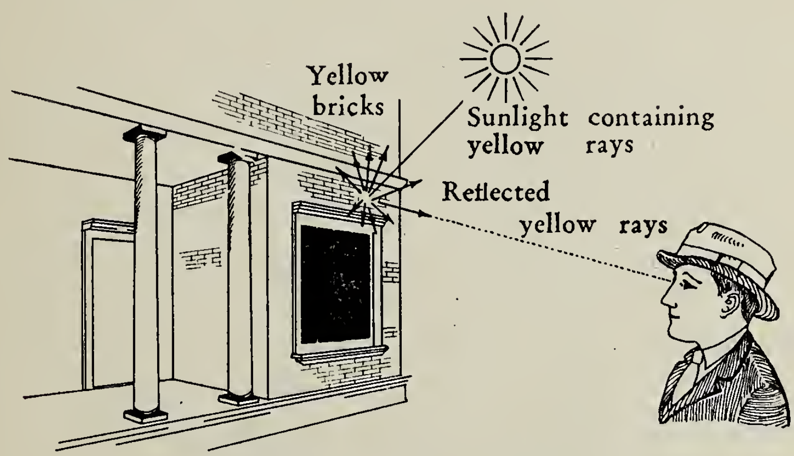

Figure 7. Color Vision

Light is affected in its passage both by distance (the law of inverse squares) and by the intervening media. Opaque bodies, of course, cut it off entirely. Translucent bodies allow its partial passage but do not permit perception of objects; transparent bodies of any given density permit the passage of light but change its direction and hence make objects appear to be where they are not. The effect of glass and other solids and of liquids and gases on the passage of light constitutes the complex and highly mathematical subject of refraction.

Reflection and absorption are of the greatest importance since the vast majority of objects are seen only by reflected light. The amount and quality of light thus coming to the eyes from, say, a sheet of

white paper depends on how much light is absorbed and how much of each wave length is reflected toward the observer. If the sheet were absolutely white, that would mean almost equal reflection of all wave lengths, but in general objects are only relatively white. Again, if the letters on the sheet appeared as absolutely black, that would mean the complete absorption of light, but no black is ever completely black, and this holds in general of colors and color combinations.

Section V

THE BEST CONDITIONS OF LIGHTING FOR NORMAL SIGHT

The sun is our chief source of light. For many generations the candle was the chief source of artificial light. At first sight it would seem far-fetched to compare candle and sun, yet in the measurement of amount of light that is just what we do. The total amount of light given out by the surface of the sun is many millions of millions of times as great as that given out by a candle, yet this immense amount can be measured in terms of candlepower. Candles had been so long in use that when newer forms of illumination came into use, they too were rated in candle-power.

Natural sources of light other than the sun and the reflected sunlight of the moon are really negligible. We can not see enough by starlight, or volcanic light, or lightning, or the firefly's light or glow-worm's, to get anything worth while from such sources except perhaps direction. So, when the sun isn't shining directly or through clouds or fog or through the reflected light from the surface of the moon, we must resort to artificial means of lighting. Even when the sun is shining, artificial light may be required for inside rooms or the sides of large rooms remote from sunlight or for special purposes in comparatively well lighted rooms. Since heated objects give out light when a certain temperature is reached, combustion was first resorted to for artificial lighting. The pine knot or pitch torch was perhaps man's first source of light for lighting purposes only as distinguished from the camp fire which was primarily for warming and cooking. Then it was found that a wick placed in oil or fat gave a steadier and brighter light. Next, perhaps, solid fats and waxes were used because of their convenience of form and easy handling qualities. In all the older lighting, the source of light is chiefly glowing solids or flames. It wasn't until relatively recent times that the actual glow of incandescent gases played much part in illumination.

With the development of modern science, illuminating gas began to be used. Its light is virtually the same, when it is lighted directly, as a candle flame, only brighter. Soon it was found that a better and still brighter light could be produced by heating solids like certain forms of ash in the gas flame. Thus the gas mantle light arose. A particularly brilliant light was produced by heating a piece of calcium to an intense glow in a gas flame.

However, lighting took its greatest steps forward when it was found that a current of electricity (of sufficient voltage and amperage), in passing through a resistant body would heat that body to a glow and that under favorable conditions that glow could be utilized for illumination purposes. It was found too that when the current passed from one body to another through a short gap, not only would heat be produced, but the particles in the gap would be heated to a special brilliance. Thus within relatively recent times the electric incandescent light and the electric arc light were discovered and made use of. Later it was discovered that electric discharges through certain gases or the arcing of electricity through certain gases or volatilized liquids (mercury, particularly) or solids (sodium, etc.) would produce very special and often remarkably beautiful lighting effects. Gradually electric lighting in all its myriad forms, and because of its high adaptability, has supplanted practically all others except in restricted localities and for certain special purposes.

Through all the developments of lighting, the old candle has remained the unit of comparison, not any candle, of course, but an arbitrarily fixed *standard candle*. Thus for measuring the power of a light at its source, we say that it is equivalent to the power of so many standard candles or that it has a certain candle-power. In measuring candle-power, a photometer is used. Since it is impracticable to measure the whole sphere of light usually produced by a source, the photometer is placed at a given distance and practically measures only a restricted beam. If, by reflectors, the total source of light can be concentrated in a narrow beam, the intensity of illumination is correspondingly raised. Thus a given automobile headlamp of 21 candle-power rating may produce a beam with a maximum candle-power of 100,000. This distinction must be kept in mind in considering the strength of a light at its source and what may be done in producing a lighting effect by directing and modifying the light. Thus the almost infinite light of the sun just goes off into space for most part; if it could all be directed by great reflectors upon such a tiny spot as the earth, in a few seconds the seas would evaporate, the solid earth melt, then turn to gas, and the whole be dissipated in one last puff of vapor!

The practical standard of illuminating power is the lumen. A sphere with a radius of one foot has a surface of 12.57 square feet. The illumination of a 1 candle-power source of light at the center of such a sphere within the angle defined by one square foot of its surface is called a lumen. In other words, a 1 candle-power light produces 12.57 lumens, the illumination being assumed to be equal in all directions.

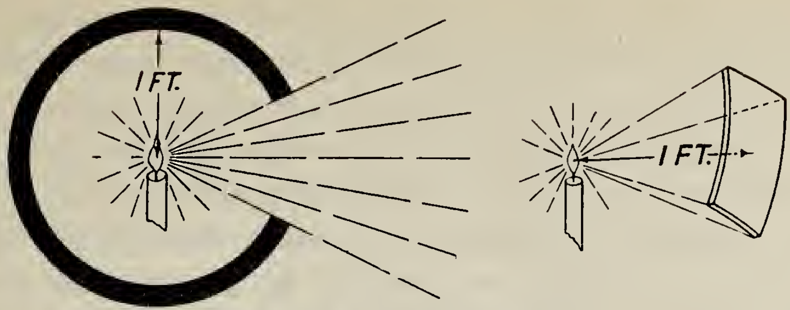

Figure 8. The Lumen

More vital for seeing purposes is the distinction between the power and total volume of light from a given source on the one hand and the lighting on a given surface on the other. Both the lumen and the candle-power are used to measure intensity at the source. The measure of the effect is the *foot-candle.* A foot-candle represents an amount of illumination equal to that produced at a point on a plane at one foot distance from a 1 candle-power source of light. For purposes of determining visibility and for such tasks as reading, the measurement of surface illumination in foot-candles is vastly more important than the candle-power of the source of light. Thus, direct sunlight on the earth gives an illumination of 10,000 foot-candles, more or less, but the candle-power of the sun is obviously millions of times as great.

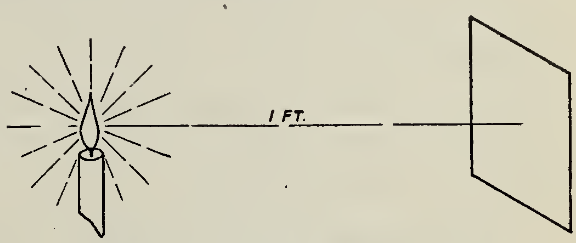

Figure 9. The Foot-candle

Foot-candle illumination must also be distinguished from surface brightness. Just as in determining the brightness of a source of light, many factors are involved, so too in determining surface brightness, color, texture, slant of beam, and other factors are involved. The reflection factor is the most important and depends largely on the color of the surface. On a painted surface of given gloss the reflection factor, or percentage of light reflected will run from 85 per cent for white to 5 per cent for black. The foot-candle is then the unit only for level of illumination and visibility depends not on it *alone,* but upon a complex of factors, with all kinds of possibilities for variation in visability.

Returning to natural light as our main source of illumination for both out-of-door and inside tasks, we are confronted with the problem of so utilizing free light as to make, *not the most of it,* but the *best of it.* We can't do much with the light itself in the open; we just have to take it as it comes. We can shut it out in part with goggles; we can redirect its course with lenses; we can reduce its intensity with smoked or colored glasses. In general, the iris and crystalline lens produce sufficient reduction and modification for all purposes. Maximum foot-

candle surface illumination on the tropical desert at noon on midsummer days with perfectly clear skies may reach close to fifteen thousand; under conditions of fog and mist even with a nearly vertical sun, the surface illumination may drop to less than one hundred. Through this wide range natural accommodation may be so nearly perfect as to make seeing reasonably comfortable, though there is a strong inclination to shield the eyes with the hands or by partial closure of the lids or lowering the brows. For such tasks as packing fruit or sorting field crops, rough sheds or brush shelters offer sufficient protection. In most cases, however, the eyes need shielding from glare rather than too much light. This is notably the case in snowfields or sandy wastes. In an orchard on the very brightest day of the year, normal eyes feel no discomfort in fruit picking; some persons can even read under such conditions in full sunlight with no marked danger signs.

The moment one enters an enclosed space, conditions alter radically. In a relatively narrow room, by actual measurement on a July afternoon at 2:00 o'clock, the illumination at the windows on the sill (east exposure) was just over 500 foot-candles, while at the wall opposite, it had dropped to only 8! One row of artificial (electric) lights had to be turned on to raise it above ten. With an increase in the number and size of the windows and especially with their tops raised two feet nearer the ceiling, daylight would have been sufficient for normally fine tasks such as reading or sewing up to 5:00 p.m. in midsummer in this same room. With the whole east side a complete bank of windows down to desk top level, blinds would have been necessary to modify the light.

This leads to the question of modification of light by ordinary semi-opaque blinds, venetian blinds, and louvres, frosted glass and other devices. The scope of this handbook will not permit a full discussion. It should be said that general principles only apply generally and that each specific case calls for special expert attention. Perhaps rather than strain too far at attaining ideal lighting under natural conditions with the sun shifting from east to west and changing with the seasons and weather conditions, it should frankly be recognized, first that with sensible if not perfect regulation of incoming light, all normal eyes will accommodate themselves to the ordinary tasks; and second, that in some rather exceptional cases as to orientation, window arrangement and so on, artificial light must be used at certain times of the day to supplement the natural light. Light consciousness and alertness on the part of teachers, foremen, and others in charge can do much toward making even a bad situation tolerable.

Where and when artificial lighting is the sole source of illumination the possibility of complete and satisfactory control rests on those

responsible for the original installation or for such changes as will bring the installation into conformity to best known practice. The quantity of artificial light can be controlled at the fixture. The light produced can be directed and modified to suit both general and special needs. Light can be directed and diffused or directed and concentrated by using various forms of reflectors. It can be modified in transmission either by the globes used in the fixture or by the absorption and diffusion effected by shades and reflecting surfaces. As to amount of light expressed by candle-power, which, it must be remembered, is not equivalent to wattage or current consumption, prescription must vary with conditions. Foot-candles of illumination on the seeing task being the true criterion of illumination, the candle-power, and by inference the wattage, must be high enough to render the act of seeing comfortable and efficient. No fine or exacting task should ever be done under less than 10 foot-candles illumination on the working surface; some tasks require up to 500 foot-candles. The lighting in between the actual working surfaces can be less but where there is a going back and forth between tasks, as in reading instruments, making notes, and consulting books, eye comfort requires that the general level of illumination be kept high.

Illuminating engineers distinguish between direct and indirect lighting, with the gradations between direct and indirect roughly distinguished as semi-direct and semi-indirect. Purely direct lighting means no shielding of the filament or other immediate source of light. Practically, light is considered direct if over 50 per cent is directed downward, while completely indirect lighting requires that all the light be directed toward the ceiling. Perfect indirect lighting would require perfect diffusion, which really means that the light comes from so many directions that no visible shadow is produced on the working surface. In practice, if all the light is first directed upward and is reflected back by ceilings, walls, and objects in the room in such a way that neither glare nor shadow effects are produced on the area under observation, the lighting is indirect. For a given source at a given distance, indirect lighting will require a larger lumen output and hence a greater current consumption or consumption of material burned than either direct lighting or the intermediate forms. While, therfore, indirect lighting is best for many purposes, if the question of costs becomes a serious one, semi-direct or semi-indirect may be the more practicable for certain installations. Thus, in a given lighting system, particularly when ceilings are high or dark or where the reflection is otherwise impeded, a 3000 lumen output of indirect light may be less effective than a 1000 lumen output of semi-indirect or semi-direct light, with fixtures properly placed and the light properly directed toward the

task. Under certain conditions, especially where older buildings, furnishings, and so on must be taken into consideration, indirect lighting is practically impossible. The greater efficiency of seeing under conditions of indirect lighting, to say nothing of comfort and elimination of nervous strain, renders systems of indirect lighting highly desirable wherever the other factors involved permit of the installation or change without prohibitive first cost or excessive cost of electric current or materials consumed.

Working surface has been given too little attention in studies of lighting and of sight conservation. Thus almost universally, desk tops are made of highly reflective materials; many machines are made with white, highly polished surfaces; automobile hoods are made as highly reflective as possible; books with glazed paper are still common (and have some justification if the printing is good); tools are nickel-plated often, with glare effects as they turn in the hands. In short, the working surface, most important in the eye-light partnership, has been given so little consideration that most practice in this connection is bad practice. In most cases correctives can and should be applied. A dull black desk surface is used in some laboratories and might be used elsewhere. Sage green or gray green blotting pads are preferable to blue or even gray. Books can be printed as cheaply on unglazed or semi-glazed papers as on highly finished papers, except where very fine cuts and photo-plates must be used and these latter can be and are introduced on supplementary leaves. It is true that sometimes to secure a sufficient contrast, high lights must appear on working surfaces; if the task is momentary, no harm results. Persistent looking at surfaces with marked glare can, however, result only in eye-strain and injury, often in actual inflammation. Here again common sense is a fine adjunct to science. Where the "counsels of perfection" can not prevail, the "best thing under the circumstances" can be done. Where surfaces glare, they can be covered, where colors are trying, like outstanding reds and blues, the color can be changed or the object removed or covered, and so on. All who have the supervision of children, handworkers, readers in libraries, harvest hands and so on, should be on the alert to save eyes, either by bringing the working surfaces into conformity with good practice or advocating colored glasses or other protective devices.

Room arrangement, both as to the placement of objects in the room and the height and frequency of light, is all important. Thus immovable desks are less desirable than movable; desks with tops fixed at one angle are not so good as desks with movable tops. Movable desks with adjustable tops, fitted to the height of the child, can be shifted and altered to meet changing directions and intensities

of natural light and are highly desirable under conditions of artificial lighting. The school room can be made a place of esthetic delight, free from glares and dangerous highlights, a place of comfort and pleasant tasks. Equally, the living room in the home can be made what its name implies, a place where one can realize the best meanings of life, with books, pictures, rugs, draperies, walls, furniture blended into a harmonious and satisfying whole by optima of lighting and of modification of light and color.

The individual study surely deserves the best. Here where creative work may be pursued, no note of inharmony should enter. The best of color schemes and of lighting should prevail, and optimum effects should be studied most carefully. What the study is to the individual, the auditorium is to the crowd, the larger groups. In stadium and field we have yet to find protection from glare and overintensities, but there is no excuse in closed auditoriums for the blatant effects so commonly encountered. Soft lights in the audience spaces; full lighting without glare or deleterious color effects on the stage; harmonies of color schemes, without distractive factors of stupid *art* badly placed—these are realized in some of the best meeting places and should be in all.[1]

[1] See Appendix A for reliable sources of information on lighting.

Section VI

DEFECTS OF SIGHT; DANGER SIGNS AND CORRECTIVES; DRUGS LIKELY TO PROVE INJURIOUS TO SIGHT

Teachers, school executives, and others charged with the eye health of children, youths, and adults in any considerable groups should ever be on the alert to detect eye difficulties and get at their causes. They should in all cases that may prove serious go beyond the simpler means of diagnosis available in charts or other easily adaptable test forms and call into consultation those of most thorough scientific training. In all cases of serious handicap, such as persistent inflammation or painful conditions of accommodation, an oculist should be consulted. More particularly those in charge should discriminate very carefully in giving advice and should resort to none but the most reliable "authority." Advertising of panaceas is especially to be looked upon with suspicion, and quacks of any rank or degree should be avoided. Under existing laws in many states two groups are authorized to conduct eye examinations. There is perhaps no quarrel with either group if it sticks to its proper field, and their differences should be reconciled in the interest of the public. Each group should develop a standard of ethics, as should all professional groups, that will limit practice to approved procedures and eliminate misleading advertising and deleterious propaganda.

With these words of precaution it is safe to proceed in pointing out a few of the more easily detectable eye defects and diseases and to indicate sources of correction. First, the danger signs are none too obvious and even serious defects and diseases may escape detection for long periods. In general any inflammation in or about the eyes should arouse instant suspicion, especially any inflammation accompanied by pus or watery discharges. Second, any abnormal growth should be immediately investigated. Opacities are especially suspect and subject to careful examination. Cuts on the eyeball or within the delicate surrounding membranes may lead to inflammation, loss of fluids, even blindness, and should be treated at once by the most competent available physician. Headaches, more particularly in the region of the eyes; pain in seeing, flashes, spots before the eyes, and similar disturbing phenomena demand immediate attention. The necessity for holding objects very close to the eyes or abnormally far from them,

or at unusual angles should lead to examination for defects in accommodation or optic irregularities. Symptoms may become constitutional, involving the viscera, to the extent of repeated and protracted nausea. Cursory or incomplete examination surely does not apply in such cases.

The most common structural defects of the eye are spherical aberration, astigmatism, chromatic aberration, diffraction, and defects due to opacities in the transparent media. Such defects are called optical defects. Defects due to failure to accommodate to distance are long-sightedness or hyperopia and short-sightedness or myopia. Defects

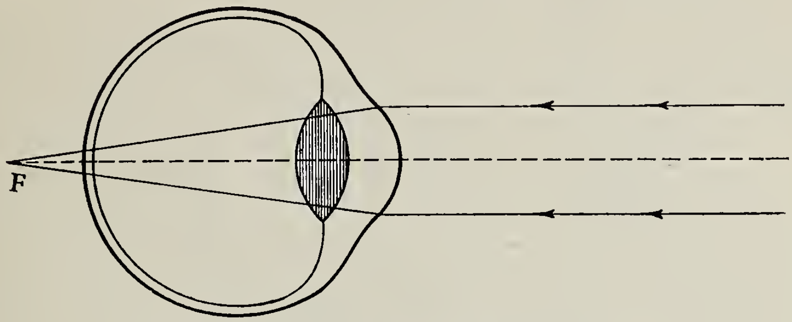

Figure 10. The Far-sighted Eye

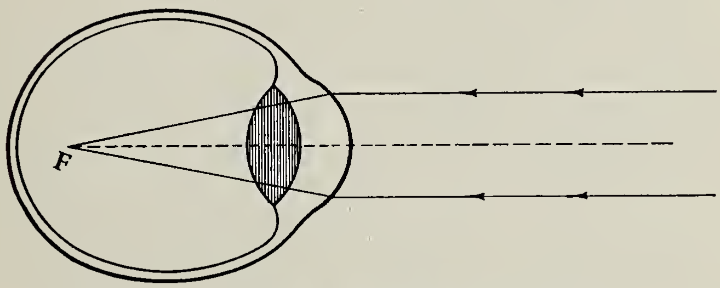

Figure 11. The Near-sighted Eye

of accommodation are the commonest and the most completely measurable. They are generally correctable by fitting with proper lenses. Astigmatism also is very commonly correctable by proper fitting with glasses. Any opacities on the surface of the cornea or in the transparent media raise the question of removal or modification by surgical means. Adaptation to light intensities should perhaps be included here. It is partly a matter of the response of the iris and partly of changing sensitivity of the retina; in either case serious lack of adaptation leads to painful results.

Muscular defects lead to incoordination in the use of the eyes as a pair for binocular stereoscopic vision. In the case of strabismus the lines of vision cross or look in divergent directions and the result is a double image. Habit leads to the ignoring of one image; hence a cross-eyed person looks at one with only one eye. These defects are very obvious; they exist in all degrees and are commonly correctable

by mechanical means or by surgery. Spasmodic innervation leads to jerky motions of the eyeballs, whether they are coordinated or incoordinated. This condition is called nystagmus. It is very common in cases of partial blindness and is accordingly really a secondary effect. It may affect both eyes or in rare cases only one. While manifest in the muscular action it is not necessarily due to muscular atony but may be purely nervous. It is to some extent an occupational disease. Nystagmus may be partially eliminated by operation when it arises from imperfect sight; in occupational cases discontinuance of the causes leads to good results. Central nystagmus from brain or cord diseases is practically irremediable.

Inflammatory diseases of the eye are very numerous. They are roughly classified by location and by the cause and nature of the inflammation. Thus keratitis is an inflammation of the cornea, commonly resulting in infiltration of leucocytes into the tissues or in focal ulceration. Loss of transparency results and may become permanent unless effective treatment is applied in time. Keratitis is distinguished into primary, secondary, and neuro-paralytic, due to the paralysis of the fifth cranial nerve. All cases of inflammation of the cornea, no matter what their causes, are serious, particularly the primary form which may easily result in permanent partial blindness. Scleritis is inflammation of that part of the *sclera* covered by the *conjunctiva.* Superficial scleritis occurs in patches and is very persistent, tending to become chronic. It leaves scars of a slaty appearance. Deep seated scleritis is more serious and may lead to weakening of the sclerotic coat. Conjunctivitis is generally an acute inflammation of the extremely delicate membrane, the function of which is chiefly protective. It arises from many infections. Some forms are very contagious, including that arising from the Koch-Weeks microbe. Epidemic muco-purulent conjunctivitis is still more serious and more contagious: it is sometimes known as school ophthalmia and may run through a whole school or school system. It may result in partial blindness, due chiefly to corneal complications. Granular conjunctivitis is more commonly known as tracoma; it is contagious, largely associated with unhygienic living conditions and a very common cause of blindness. Diphtheritic conjunctivitis, not necessarily associated with diphtheria of the throat, occurs chiefly in children under four; its results may be very disastrous, as may those of a similar streptococcus infection of the conjunctiva. Conjunctivitis in its various forms ranks with keratitis in being one of the two most common inflammatory conditions of the visual organ.

The iris may be inflamed from various causes. This condition is called iritis. Photophobia or extreme sensitivity to light is the most

marked symptom. An acute attack generally lasts about six weeks but is likely to pass over into a chronic condition. In chronic and recurrent iritis very serious consequences to vision are likely to follow from adhesions or other complications. Infections or injuries in the ciliary body may lead to ciliary inflammation or cyclitis. The variations are very similar to those of iritis.

Choroidal and retinal inflammations are less common than the preceding. Glaucoma is the most common disease of the interior of the eye. It is accompanied by severe tension of the eyeball, hardness to the touch, and results fatally to sight unless its course is checked. The retina itself is subject to inflammation, to detachment from the choroid, to hemorrhage, and to tumor. The inflammation, retinitis, especially the form called retinitis pigmentosa, may cause loss of sight. And lastly, the nervous structure, including the optic nerve, is subject to inflammation with possibly fatal results due to atrophy.

Most infections if taken early can be controlled, with consequent avoidance of loss of sight in any degree. The earliest symptoms, redness of the exposed parts due to hyperaemia, watery condition, pains, flashes of light, headache, and swelling, especially in cases of suspected epidemic, should lead to immediate superficial examination by the school nurse, the passing on of the suspect case to the physician (oculist), and to treatment and perhaps isolation. The writer, when a boy, has seen conjunctivitis of a rather dangerous type sweep unchecked through a large rural community, passing from home to home, school to school. Such epidemics should be banned under even backward and underprivileged conditions.

A word should be said about those changes in the eye that come as a result of increasing age. Presbyopia, or lack of resiliency in accommodation due to age, is the commonest. The far sight remains normal or nearly so but near objects look blurred: hence the tendency to hold a book or a small object under observation at greater rather than smaller distances from the eyes. The corrective is usually simple: the onset of this condition, usually at about forty-five years of age, should lead to a careful eye examination and fitting with glasses. Old age cataract, leading in many cases to total or nearly total blindness, is also very common; as in other cases of cataract operation for removal or partial removal may be successful. Many other alterations of tissue due to old age may lead to partial or complete loss of sight. These alterations are not necessarily due to age as such; in fact they are rather the result of long-continued but often suddenly appearing causes, that become more apparent as age advances. This is notably true in cases of anaemia and of hidden toxic conditions due to syphilis and other degenerative diseases.

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In all matters of visual defect, degree is an important factor. What is to be done depends largely upon a clear recognition of its importance. Thus many opacities permit of partial vision which is far better than none. For the oculist to rush the patient into a doubtful operation with actual risk of residual sight is as criminal as neglect. Fitting with glasses where no real inconvenience is experienced by the patient is almost as bad as fitting with the wrong lenses. Science and common sense should be closely allied in these matters. Alarmist attitudes are dangerous; too many nurses and others concerned with health, including eye health, communicate a sort of pathology to those around them. Only correct diagnosis with accurate and, if necessary, repeated measurements can lead to successful prognosis and beneficial treatment, and even the accurately and thoroughly trained may make mistakes. The approach in a thing so precious as sight should be not only scientific but almost reverent—at least cautious.

Because of the element of variation expressed in measurable differences where any pathology is indicated, even very superficially, examination is an immediate necessity. Chance one way or the other, or rather *chancing* the "natural course of events," is dangerous. Since, too, variation is not only to be found in cross-section comparisons but also in linear comparison, i.e., in the same person at successive times, an indication of defect or of pathological conditions should be followed up by repeated tests and examinations. This point will bear repeated stressing.

Anything that can be said in this compilation with regard to general eye hygiene is necessarily largely negative. To give positive advice would be to trespass on dangerous fields. The safest advice is that of consultation with the most thoroughly trained and competent authorities. This applies in matters of lighting as definitely as in all things relating to examination and treatment. Another thoroughly safe generalization is not to neglect symptoms of visual trouble. It is safe to say, also, that washes, ointments, salves, or other preparations should not be applied to eyes, especially inflamed eyes, except on prescription. Even so harmless a preparation as a saturated solution of boracic acid may be dangerous in cases of inflammation, may be in fact just the thing not to apply. The removal of a cinder or other foreign body, simple though it may seem, is hardly a job for an amateur; and the inexpert treatment of cuts, bruises, or lacerations in or near the eyes involves too much danger from infection, loss of fluids, or other actual or potential involvements. Here again degree is most important, and the teacher, parent, or nurse must use good sense. One need not run to a physician with a mere scratch or a mosquito bite.

The following notes on the deleterious effects on sight due to certain drugs are contained in a paper by Dr. Clara L. Kohls of the University of California, Department of Anatomy, and published here with her permission.

EFFECTS OF CERTAIN DRUGS ON SIGHT

The various drugs which, under certain conditions, have been known to impair vision or to cause eye diseases, or blindness, may be grouped according to the kinds of eye symptoms which they produce.

Drugs which are sometimes found to be the cause of conjunctivitis include atropine, eserin, crysophanic acid, arsenic, tobacco and similar irritants, and aniline dyes.

In the conjunctivitis caused by atropine (and sometimes by eserin) in individuals especially susceptible to these substances, the lids become swollen, tense, and red. The conjunctiva often shows follicles, and even, in rare instances, a membrane may appear. The cause of this particular type of conjunctival irritation is uncertain; but it is probably most often due to some impurity in the special brand of drug used.

Beginning with 1933-1934, an important number of cases have been reported in medical literature, in which serious dermato-conjunctivitis has ensued upon the use of eyelash dye solutions containing aniline derivatives. One medical journal reports six cases of severe conjunctivitis and two cases of keratitis, one with ulceration, resulting from the cosmetic use of henna, which had been thought to be harmless to these tissues. The Board of Medical Examiners of California states: *"It is serious to use a solution of unknown content around the eyes. Some of them contain aniline derivatives, and may cause blindness, or serious dermatitis."* [1] The *Journal of the American Medical Association, British Medical Journal,* and *German Medical Journal* report such cases.

The use of dinitrophenol as a means of controlling obesity is attracting much attention because of the alarming number of cases of cataract which have developed following its use. A recent news item reports 100 cases of cataract now existing in Los Angeles as a result of use of commercial weight-reducing preparations containing dinitrophenol.

Late issues of the *Journal of the American Medical Association* record detailed case histories of similar cases observed by physicians in various localities.

Certain drugs cause acute retrobulbar neuritis. Alcohol and lead are the best known causative agents of this distressing condition. The symptoms consist of severe headache which is usually unilateral and

[1] Editor's italics.

on the side of the eye involved, pain in the orbit, aggravated by eye movement and pressure. Impairment of vision comes on rapidly, beginning from the center of the field and progressing in the course of a week to complete blindness. Externally the eye appears normal.

A few drugs cause disturbance in color perception. Ethyl alcohol (ordinary alcohol in alcoholic beverages) when taken in small doses increases the acuteness of color vision for both red and green. Large doses, however, markedly diminish the ability to perceive colors normally. In tobacco amblyopia (which is fully described below) there is central color scotoma (color blindness) for red and green.

Santonin, which is a highly toxic preparation sometimes used in treatment of roundworm infections, may cause poisoning characterized by partial blindness, accompanied by "yellow vision."

The remaining category of visual disturbances caused by drugs is the group of conditions known as toxic amblyopia, or dimness of vision.

A not uncommon type of this condition is tobacco amblyopia. This condition usually results from excessive use of tobacco, either by smoking or chewing, though it may occasionally occur in workers in tobacco factories from the absorption of tobacco dust. Shag and tobacco mixture cause the most trouble. In nearly all cases, though not invariably, overindulgence in alcohol is a concomitant factor. The patient may have smoked excessively for years with impunity, some intercurrent cause of debility, gastro-intestinal disturbance, etc., being the immediate precipitating cause of the attack of amblyopia.

The chief symptoms of this type of amblyopia is increasing fogginess of vision which is least marked in the evening and in dull light, and which is most marked in bright light. Central vision is greatly diminished, and, as previously remarked, a characteristic symptom is a color scotoma for red and green. The latter is usually small, involving a horizontally oval area between the fixation and the blind spots. In rare instances, it may extend beyond the red field (or even be absolute). In tobacco amblyopia, as a rule, both eyes are about equally affected.

The condition is chronic and the prognosis is good, *if the toxic agents are discontinued absolutely.* Very rarely optic atrophy results, but it is doubtful if the etiology of these cases is uncomplicated. The process involved in the development of this disease is not completely understood, but it is probably based upon poisoning of the ganglion cells of the retina by the toxic substance. Since the ganglion cells of the fovea and macular region (point of most acute vision) are the most highly differentiated, they are liable to suffer first and most severely in this condition. In the case of tobacco, nicotine is generally thought to be the toxic agent, but it is much more probable that one of the

decomposition products of nicotine is the factor responsible for this condition. Other substances capable of causing an amblyopia resembling that produced by tobacco include carbon disulphide and iodoform.

Another type of amblyopia is produced by quinine, less often by ethyl-hydro-cuprein, and, occasionally, in a milder form by salicylic acid and salicylates. Amblyopia caused by this group of drugs differs strikingly from that produced by tobacco. In quinine amblyopia, total blindness follows the use of the drug. In less marked and in later cases, the field of vision is much contracted. This may occur following as small a quantity as 12 grains in a specially susceptible person. In the average individual, 40 grains is the maximum amount of quinine sulphate which can be consumed without deleterious effect over a 24-hour period. During the period of recovery the fields of vision gradually widen out, but do not regain their normal limits, although central vision may be completely restored. Occasionally blindness is permanent and optic atrophy ensues.

Methyl alcohol (wood alcohol), arsenic, lead, nitro- and dinitrobenzol, filix mas and sometimes chloral and aniline cause a third and more serious type of amblyopia. This differs markedly from the retrobulbar type. More serious optic atrophy generally ensues. The central scotoma characteristic of amblyopia probably occurs in all cases at some stages, but it is often missed in the rapid progress of the disease to total blindness.

When methyl alcohol is the toxic agent, vision fails very rapidly, passing through the stages of contracted fields and absolute central scotoma to total blindness. Later the vision may improve but if so it usually relapses. In the usual course of the disease, progressive optic atrophy destroys vision. Rarely, however, restoration of vision is complete and permanent.

Arsenic is especially liable to cause optic atrophy, usually total, when administered in the form of trivalent benzol ring compounds (e.g., atoxyl, arsacetine, hectine, etc.) which are used to destroy the trypanosome of sleeping sickness. The salvarsan group of arsenic compounds is less toxic; no cases of optic atrophy have been reported as a result of their use.

In lead poisoning, the ocular signs may include optic neuritis, and optic atrophy which may be primary or post-neuritic. Some cases exhibit retinitis, either directly due to the lead, or to albuminuria, secondary to lead nephritis.

Filix mas, used as a helminthetic (a remedy for worms) may cause amblyopia if taken in excessive doses, especially if taken with castor oil. This condition is said to resemble quinine amblyopia ophthalmoscopically. Later, however, optic atrophy supervenes as in the amblyopia caused by methyl alcohol.

It will be noted that Dr. Kohls has not dealt with temporary drug effects, but only those likely to prove chronic or permanent. Many drugs, notably ethyl alcohol and hashish, have marked effects upon vision for varying times and with varying intensities. Incoordination resulting in double vision follows even a moderate drinking of alcoholic beverages. In extreme alcoholism hallucinations occur, with such compelling force as to dominate the victim completely. These are almost invariably visual. Practically all narcotic drugs have similar effects.

Section VII

CERTAIN FINDINGS WITH REGARD TO READING

This section is supplemented by three notable short papers and can, therefore, be very brief. Enjoyment of reading depends largely, of course, on the strength and condition of the eyes. Determination of these factors is a matter of examination by experts. Aside from eye strength and eye condition the main factors involved in comfortable and efficient reading are printing, lighting, and reading habits. The writer takes it as his function to present a summary of results and let the experts speak as to detail.

Printing involves texture, thickness and color of paper, size and clearness of type, type and paper contrast, size of the page, length of the line, the spacing of words, the spacing of lines, the use of illustrations and binding.

Other things being equal (which may be understood to be repeated for each statement here presented), papers of fairly rough texture are preferable to very smooth papers. Gloss effects are tiring though sometimes they are essential for bringing out cuts. Overrough papers cause type blur. A finish just between rough and gloss allows clarity of type and permits sufficient contrast. Sight conservation books use a rather rough paper with some tinting, but the type is very large and exceptionally clear and the cuts used are of the heavy shaded types. Thick papers are desirable because of their opacity: where the reverse page can be seen through the sheet or even the page opposite on the next sheet, the effect is often very annoying. Thin India paper has largely been discontinued for this reason. Thinness has another fault than lack of opacity, namely the difficulty of turning leaves. While this is not an eye factor its temper-correlation is very high! Colored or gray papers are restful only when they permit of high contrast and do not distract from the main purpose of printing, which is to enable the reader to read with ease. Soft yellows are very restful and give excellent contrast. Greens would seem to commend themselves but lower the contrast factor. Non-gloss white or slightly gray papers seem best for all-round purposes in printing, as they permit maximum contrast without distressing high lights. Pure colored papers and colored inks are permissible for special purpose printing but hardly enter into the general problem.

Size of type has been found by experimentation to be less important than clearness. Clearness depends upon line width in the type and upon the relationship of parts. A heavy type is not necessarily clear any more than a large type. The meaning of this may be illustrated in the attempts to make so-called Old English or German type more legible. The letters had to be greatly simplified and the width of lines in the different parts of a given letter made more nearly uniform. The illustrations presented on the next page show the factors involved better than pages of description.

Length of line is very important. Column divisions are made almost without regard to reading needs and correct reading habits. If pages are moderate in size, column division is of doubtful utility. When eye span is taken into consideration, the size of the page or width of column can be determined for the average trained reader with fair scientific accuracy. Personally, I am somewhat dubious about the relatively long lines in some sight conservation books. This factor should be given serious consideration by those responsible for the preparation of these books.

Likewise, both letter and word spacing ought rather to be determined by the habits of mature and properly trained readers than by the exigencies of printing. Words are, of course, more or less artificial abstractions, but no one has yet suggested groupings that follow both thought units and normal eye movements. Some approach is made in word compounding in such languages as German and in similar more or less sporadic attempts in highly analytic languages like English, such as "on a never-to-be-forgotten day." The desirability of actual word grouping in printing, other than by standard signs of punctuation, quotation marks, italics, etc. is highly debatable. Line spacing, on the other hand, is largely an optical matter. That fairly wide spacing presents much easier reading no one can doubt who has noted the difference in double and single spaced typing.

As to the use of illustrations and their proper insertion, little need be said. It is commonly asserted that savages and little children can not be interested in photographs or photographic cuts. However true this may be, that is, however little they may see in highly detailed and continuous illustration, the converse is undoubtedly true, namely, that relatively heavy lines and bold contrast of light and shade and of color make for quicker perception and more lasting impression. For many purposes illustrations should be diagrammatic or nearly so. For most readers they must steer clear of mathematical expressions other than of the simplest sort. Many scientists successfully hide their light under a bushel of involved language, poor printing, and complex illustration.

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Example of the So-called Old English or German Type

Size of type has been found by experimentation to be less important than clearness. Clearness depends upon line width in the type and upon the relationship of parts. A heavy type is not necessarily clear any more than a large type. The meaning of this may be illustrated in the attempts to make so-called Old English or German type more legible.

A Legible Type Frequently Found in Modern Books

Size of type has been found by experimentation to be less important than clearness. Clearness depends upon line width in the type and upon the relationship of parts. A heavy type is not necessarily clear any more than a large type. The meaning of this may be illustrated in the attempts to make so-called Old English or German type more legible.

A Specimen of Type Commonly Used in Elementary School Textbooks

One would think that binding is unimportant to the general problem of reading; but on the contrary it is an essential factor. Binding with too narrow inner margins is one of the worst sins in book making. Overstiff binding is almost equally annoying. In general, a book is well bound and contributes to the comfort of reading most if it opens out fairly flat and never conceals parts of the printing or illustrations unless forced open, and never necessitates uncomfortable angles in reading or presents distressing high lights on curved surfaces.

Lighting and reading habits are both so completely treated in the three following papers or in other parts of this handbook that it seems superfluous to treat of them here.

SOME ASPECTS OF THE HYGIENE OF READING

Hugh V. Brown, Opt. D.

The hygiene of reading is a very important phase of the problem of eyesight conservation. There is such a vast amount of printed matter of every description today, and the eye is occupied so much of the time by following the printed line, that every possible effort should be made to prepare the printed page so that it may be read with ease and comfort.

The effort of the eyes to see clearly under adverse conditions is referred to as eye-strain. It should not be inferred that eye-strain results *only* when some eye defect exists. It is true, of course, that defective eyesight is one of the important causes of eye-strain, because abnormal strain is placed upon defective eyes in their effort to see clearly. But, on the other hand, if normal eyes are abused or misused, eye-strain, likewise, will inevitably result. Furthermore, the trouble does not end with the eyes. Through causes understood only in part, the effects of eye-strain may be manifested in other parts of the body, as the head, stomach, neck, or back. The bad effects resulting therefrom are headache, nervousness, general fatigue, faulty digestion, sleeplessness, inability to concentrate the attention, irritability, poor work, accidents, and inefficiency. The causes of eye-strain are uncorrected eye defects, improper lighting, and general misuse of the eyes such as long periods of close application without frequent intervals of rest, too much fine work requiring accurate discrimination of details, reading of fine print, etc.

The term *hygiene of reading* in its broadest application covers the various aspects of the act of reading, such as:

1. The movements of the eyes
2. The speed of reading

3. Typography of the printed page
4. The surface finish of the paper
5. The relationship of color of print to color of paper
6. The relative legibility of various sizes and styles of type, etc.

Nature of eye movements

As we read, the line of sight moves across the page. You know what happens if you move a camera while you are taking a picture; all that you get on the film is a blur. Likewise, the eyes must be still, if the image is to be recorded, and so they stop in their forward movement from time to time. These stops are called *fixations*, and it is during these fixations that we read. It is not necessary to stop for every letter, or even for every word, as the eyes can take in several spaces at a single fixation.

The eyes should proceed across the line of print from the left end to the right in short jumps; they then take a long jump back to the left end of the following line. Sometimes, however, the intent of what is read is missed and the eyes take a backward jump on the same line. These backward jumps along the same line are called *regressions,* and are a definite handicap to rapid reading.

A skilled reader's eyes move in a definite rhythm—that is, they jump evenly across the line, stopping about the same number of times on each line, pausing the same length of time at each fixation, and taking in about the same number of spaces at each fixation. The more fixations a line that are needed, overlong fixation pauses, too many regressions—all these lower the efficiency of reading. So also, if there is lack of accuracy in the long jump which the line of sight makes from the end of one line to the beginning of the next, the reading is not effective. Of course, the standard for these different habits varies with the type of reading matter.

Reading is the key to all other subjects. Research has shown that more than 60 per cent of the failures and problem cases in the schools can be helped by individual reading instruction after proper correction of refractive defects and other remedial measures have been employed.

It is not unusual to find pupils in the sixth and seventh grades still struggling with the same reading habits they used in the second or third grades.

Whenever faulty eye-movement habits are discovered, teachers should regard them as symptoms of some fundamental difficulty—not as causes of poor reading. They are to be eliminated by finding and correcting the real difficulty, not by attempting to ''pace'' the eye-movements as some have attempted to do. In other words, desirable

eye-movement habits are not developed by direct teaching, but are a by-product of correct reading instruction.

The reading readiness of a child should be known before instruction is given. The factors considered in determining reading readiness include:

1. Absence of ocular pathology
2. Condition of binocular vision
3. Stereopsis level
4. Ocular poise, both lateral and vertical for both distance and near vision
5. State of refraction
6. Degree of fusion

Tests for the above factors must be given by a trained expert.

In considering the printed page the following factors are most important:

1. General layout
2. Amount of leading
3. Spacing
4. Size of the type or types used
5. Color and degree of gloss of the ink
6. Color of the paper and its density, texture, and finish

But equally the printed page must be considered in relation to:

1. Level of illumination available
2. Chronological age of the child
3. Mental age
4. Subject-matter
5. Time available in the school program for reading

In the past the personal tastes of the printer have largely determined practices in paper manufacture as to texture, finish, and color. The manufacturers have had no set of standards on which to base good practice and in trying to serve a multiplicity of demands have simply added to the confusion. With development of new methods of measurement of reflection, contrast, fatigue effects, and the other factors involved in a seeing task, the excuses for bad practice are largely eliminated.

Taking reading as a seeing task, the most important factors in its analysis are:

1. Visibility
2. Legibility
3. Speed and accuracy in the act of reading itself

In testing visibility a mark is made upon paper by a letter and then the distance determined at which the eye ceases to distinguish the letter from the paper. Or a letter may be singled out from a group and the distance determined at which the single letter merges into the group. Visibility varies directly with the intensity of the illumination.

Legibility bears a direct relation to:

a. Shape of the letters, i.e., whether Roman, Gothic, or other style
b. Ratio of the height to width of letters
c. Thickness of main strokes and hair lines, and
d. Internal and surrounding white spaces

The criteria of legibility naturally divide themselves into three divisions, which may conveniently be designated as objective, subjective, and functional. On the objective side we must find measures that give us standards of dimensions and ratios of dimensions of the printed symbols. Under the subjective we find such factors as fatigue and eye-strain and esthetic satisfaction or the reverse. The functional aspect covers distance threshold, illumination threshold, focus threshold, the speed of reading, and the errors of reading.

As speed of reading has become so important both in school work and in life outside the school, it deserves further analysis. Without attempting to be exhaustive and also without too meticulous care in naming comparable elements, we may list the main speed factors as follows:

a. Power of comprehension
b. Natural alertness
c. Nature and degree of vocalization
d. Eye-movement habits
e. Early training
f. Practice, daily amount, etc.
g. Purpose of the reading in hand
h. Attitude with regard to material read
i. Nature of the topic or topics
j. Word length and variation in length of words
k. Rate of convergence accommodation of the eyes

Scholastic progress is enhanced when the study program is planned in relation to the time of day. Severe visual tasks should be undertaken only when adequate light is available. This encourages proper posture, accurate work, less eye-strain, etc.

There is a need for statistics of the prevalence of visual defects among school children. If the sight conservation program is to be successful, it will be necessary to have some evidence of the reduction of

defects. In cooperation with school surveys, and authorities, record forms and methods of procedure are ready for making school surveys. Some work has been done in New York and other states by the optometrists, nurses, and school physicians, jointly assembling the data. The optometrists examined the visual functions, the nurse supplied the home life background material and checked with the parents to see that the recommendations were followed, and the school physicians made semiannual health examinations. Then in some cities the school principal acted as the chairman of a coordinating council to study the data assembled of those children who did not show normal progress. As said before in this paper, reading instruction is an important means of coping with problem cases.

THE EYE HYGIENE OF STUDY AND HOME READING

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Almost everyone who has done any appreciable amount of study or home reading has often found that he could do it only at the expense of tired eyes, headaches, and physical fatigue. To the reasoning mind this immediately raises the questions:

1. Are the eyes in proper condition?
2. Are the reading conditions correct?
3. Is this fatigue that accompanies reading a normal phenomenon?

Some of these questions may be readily answered. First, the question of the condition of the eyes should be settled by having a competent eye specialist make a comprehensive eye examination. The results of such an examination may necessitate, under extreme conditions, medical or surgical assistance. In other cases only glasses may be required, and for the fortunate person the examination will disclose normal eyes that require no correction.

Usually even after one's eyes have been conditioned by an eye specialist any extensive study or reading produces fatigue. However, one finds that the amount of fatigue varies from time to time. Thus when one is on a vacation he may sit on an open porch and read a novel through in the course of an afternoon without any attendant eye fatigue. Again he may find that he can read a newspaper for only perhaps fifteen minutes at night before his eyes start bothering him. Apparently the seeing conditions vary in the two cases, being correct in the first case and incorrect in the second. The fact that several hours of reading under proper conditions could be done without fatigue indicates that the fatigue that so often accompanies

reading is not a normal phenomenon. The desirable thing therefore would be to try to secure conditions at night comparable with those in the day time.

A careful study of this problem shows that it is more complex than one would at first suppose, and before definite conclusions can be drawn additional questions must be answered.

4. How does the amount of light available for seeing compare in the two cases? More specifically, how does the level of illumination on the book that was read on the open porch compare with the level of illumination at night in the living room?

5. Is the reading of a newspaper a more difficult seeing task than the reading of a well printed book?

6. If our seeing tasks vary, is there any way of making them less difficult, or still better, making them all equally easy?

Measurements will show that the level of illumination on the book read on the open porch in the afternoon was perhaps 100 foot-candles.

A study of the reading tasks involved in the two cases brings out the fact that one sees by the difference in brightness between an object and its background. Also, one learns that the larger the object, the easier it is to be seen. Now the novel was probably printed with a fair sized type, well spaced, using black ink on a good quality thick white paper. Thus each letter was easily discernible. On the other hand, the newspaper used comparatively small type printed with what amounted to dark gray ink on a grayish-white paper which was thin enough to allow the print on the other side to show through a trifle. Measurements with a visibility meter would show that the newspaper was at least 3½ times as difficult a seeing task as was the novel. Further investigation would show that if 3½ times as much light were provided for the newspaper as was provided for the novel the reading of the newspaper would be as easy a seeing task as the novel was. However, the novel had a level of 100 foot-candles on it. On the same basis 350 foot-candles would have to be provided for the newspaper! Consequently there is small wonder that one could not read the newspaper at night with ease.

On reaching this point one immediately realizes that with our present lighting technique it is absurd to even consider providing 350 foot-candles in the average home at night. One immediately thinks how uncomfortable the present bare lamps are that are so commonly used in wall brackets and central living room fixtures. Again one may recall how uncomfortably bright the lamp bulbs are of a bridge lamp as they are seen under the colored shade. Consequently some more questions are raised.

7. What might be considered a standard reading task?

8. What level of illumination should be provided for this standard reading task to secure a standard seeing task?

9. What levels should be provided for common reading tasks to make them similar to the standard task?

10. Would it be permissible and desirable to provide a moderate level of illumination throughout a room and then superimpose high levels of illumination at the places in the room where severe seeing tasks are being conducted?

11. Could a general recommendation be made as to the level of illumination that should be provided for average reading tasks?

12. Can anything be done to minimize the discomfort that bare bulbs or glaring lights inflict on the eyes?

13. Do room finishes or decorations affect or modify the reading problem?

14. Do room finishes influence the lighting that should be used?

15. Are there any general rules as to choice of room colors that may be followed that will help reduce the severity of the seeing tasks?

16. Is there any means of determining whether or not a reading lamp will give satisfactory illumination?

17. Are there any reading and study habits that are conducive to sight conservation?

Only tentative answers can at present be given to many of these questions and doubtless as sight conservation work advances these answers may be considerably modified. The *Readers' Digest* is at present being recommended as a standard reading task. It has moderate sized print on a good quality, white paper, and the results of many experiments conducted by different engineering and psychology laboratories indicate that 10 foot-candles of well-diffused light on the regular printed page of The *Readers' Digest* will constitute a normal seeing task, one that the eyes can handle quite satisfactorily. The following tabulation lists some common reading tasks and the levels of illumination that must be provided to make them comparable to this standard seeing task.

Foot-candles	*Material*
5	12 point type, best white paper
10	8 point type, best white paper (*Readers' Digest*)
25	Pencil notes on white
35	Newspaper text
55	Telephone directory, the yellow pages
75	Typing on dark blue paper
80	Newspaper stock market quotations

From this tabulation it appears that if 25 foot-candles of well-diffused light were provided for study and home reading it would suffice for the average seeing task encountered in such work. It is true that at times more light would be provided than is absolutely essential and at other times not enough light would be provided. However, 25 foot-candles is a considerably higher level than is at present provided and it has proved to be quite acceptable.

Tests have shown that brightness ranges of 100 to 1 may be encountered without objectionable effects on the eyes. This range in brightness can be approximated in average rooms if the range in levels of illumination throughout the room is not greater than 10 to 1. Consequently, if the highest level in a room is perhaps 50 foot-candles the general illumination should not be less than 5 foot-candles.[1]

Bare lamps should never be tolerated. The only permissible exception to this rule is for the case of the very low wattage, large diameter ivory or colored lamps that are designed primarily for decorations rather than lighting units and even then they should be used only when absolutely necessary. Such lamps should never be over 25 watts and should be 3 inches or more in diameter. All ordinary lamps should be enclosed by either large diameter enclosing globes or large sized shades of parchment, silk, or other diffusing materials, so that the surface brightness of the lighting unit will be low. Lamps which have their shades so designed that it is impossible to see the bare bulbs when the lamp is in normal use should always be selected.

Room finishes have a decided influence on the lighting effects. Ideal conditions appear to be a ceiling just off of white in color, which will reflect about 80 per cent of the light that falls on it. The side walls of the room should have a reflection factor of 50 to 65 per cent. Totally indirect floor lamps can be used in such a room to send the light to the ceiling from which it would be diffused throughout the room, producing a soft, shadowless light. Pastel shades of green, blue, and yellow, also light grays, creams, ivory, and even white where there are sufficient draperies and bookcases to reduce the average wall reflection to around 50 per cent may be used and will be restful to the eye. On the other hand, reds, browns, brilliant yellows, and dark greens, blues, and grays are apt to be tiring to the eyes and extremely difficult to sight because of the severe contrast between the light sources and the dark colors.

The Illuminating Engineering Society has drawn up rigid specifications for reading and study lamps and floor and bridge lamps and

[1] To give an average of 25 foot-candles on a book or the working area of a desk a lamp is usually required that produces a maximum level of 50 foot-candles of light adjacent to it.

5—39444

their shades, and arrangements have been made whereby lamps manufactured to these specifications can be tested. All lamps that have been found by test to meet these specifications are labeled with tags certifying their compliance with these specifications. Since the certifying tags bear the initials of the Illuminating Engineering Society, these lamps are commonly called I. E. S. lamps. If a lamp bears an I. E. S. tag one is assured that it is a quality product and that it can be relied upon to produce a level at the normal reading position of at least 25 foot-candles throughout a moderate sized room with a light ceiling if it is a totally indirect lamp.

Lastly, one can materially reduce eye fatigue by developing the habit of reading continuously for a period of not over fifteen minutes and then closing one's eyes for a minute or two before resuming the reading. When reading for study purposes this pause enables one to review mentally what has just been read and thus help to fix the material in one's mind. When reading for pleasure it provides intervals for reviewing material just read. These pauses also permit one to stop and consider how the plot will probably develop and also give one time to really appreciate the author's style and charm of presentation. In fact, once one has acquired this reading habit one is apt to be as scornful of the reader who reads continuously as is the wine connoisseur of the person who gulps his wine down instead of sipping it and thus enjoying its full flavor. A word of precaution, however, should be added. When actually reading one should read as rapidly as possible and still read understandingly. The art of rapid reading is as important an acquisition as is the habit of giving one's eyes rest intervals while reading.

Many of the problems involved in the eye hygiene of study and home reading can be satisfactorily answered after means have been devised to measure accurately eye comfort and visual fatigue. It is to be hoped that before long sight conservation organizations will develop techniques whereby these measurements can be made accurately.

SIGNIFICANT EYE-MOVEMENT HABITS

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Eye movements are symptoms of the processes which go on in the central nervous system and as such furnish the means of making objective studies of what takes place in the experience of the reader. As early as 1879, attempts were made to study eye movements by direct observation. Somewhat later the telescope was brought into

service. Another approach was made by attaching a microphone to the upper lid and counting sounds made by the movements of the eyes. In 1891 an investigator succeeded in attaching to the cornea an ivory cup with a connected pointer; he failed, however, to secure satisfactory records. Somewhat later a plaster of Paris cup replaced the ivory cup: to the cup was attached a light thread leading to a recording lever. The next approach did away with apparatus attached to the eye, and made use of photography. Subsequently direct photography supplanted photography of the movement of a line reflected from the surface of the cornea. Major and minor modifications during the last thirty years have resulted in the development of apparatus so refined that the movements of both eyes can be recorded simultaneously on moving film by photographing beams of light, reflected first to the cornea from silvered mirrors and then from the cornea through the camera lens to a moving film. Eye-movement photography has made possible a great number of experimental investigations relating to reading, arithmetic, spelling, algebra, chemistry, music, typewriting, and even art.

The objective data from these studies must be regarded as highly significant for educational psychology. A complete summary of the findings from the eye movement studies is obviously impossible in the short time permitted for this paper. Accordingly, a few important points have been singled out and will be treated briefly in question and answer fashion.

Question 1. What was the early belief regarding the eye movements in reading?

Answer. People generally believed that readers made a sweeping, continuous movement from the beginning of the line at the left to the end of the line at the right. It was the popular belief that Theodore Roosevelt, a super-reader, could read an ordinary novel in thirty minutes. It was thought that he did not find it necessary to sweep his eyes from the beginning to the end of the line, but rather that he fixated on the middle of the first line and then moved down the page from top to bottom.

Question 2. How did we come to discover the error in this belief?

Answer. Alert observers of human action discovered that the eye in reading moved in what seemed to be short jumps and stops as people surveyed the line of print. Interest in this observation led to the development of apparatus so refined that we are now able to record with a high degree of accuracy the movements which the eyes actually make in reading, in adding columns of figures, in looking at pictures,

and so on. The record is secured by reflecting a beam of light from the cornea of the eye upon a moving film. By cutting this light at constant intervals of time we are able to locate the point of fixation and calculate the duration of the fixation pause.

Question 3. How do the eye movements of mature readers differ from the eye movements of immature readers?

Answer. The fixations of the immature reader are more numerous, the duration of the pauses is longer, and the order of fixations more irregular. (1)[1]

Question 4. What is the nature of the progress that characterizes eye movements during the progressive stages of learning to read?

Answer. The progressive stages in learning to read, from the initial effort of the beginner to the seasoned performance of the mature reader, are accompanied by gradual reductions in the number of regressive movements, and by an increasingly smooth and regular sequence of saccadic shifts along the lines of print. (1)

Question 5. What sequence of eye movements characterizes the typical reading of the mature reader?

Answer. The sequence of eye movements of the mature reader is characterized, in typical reading, by a fixation near the beginning of the line, followed by two or three or four short fixations distributed over the line.

Question 6. Are the eye movement patterns of all mature readers identical?

Answer. No. Eye movement patterns, like other characteristics, vary with individuals. (16)

Question 7. Are eye movements the same for all types of reading? (4)

Answer. No. Variations in the sequence, number, and duration of pauses have been found to be dependent on whether the material is read

a. for oral reproduction (10, 7)

b. to typewrite (6)

c. to proof read (7, 16)

d. to study (10)

e. to learn to spell (9)

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[1] The numbers in parentheses in this section refer to similar numbers in Appendix B.

Similar variations accompany changes in content. Eye movements have been noted to differ in response to changes in

a. difficulty (12)
b. subject-matter (16)
c. arrangement of words (1)
d. familiarity with the language (2)
e. type of reading symbols, including numerals, notes of music, etc. (1, 7, 14)

Question 8. What constitutes a mature rate of recognition?

Answer. Rate of recognition varies with varying conditions, purposes, and degree of familiarity with content. In easy reading from $5/25$ to $6/25$ of a second approximates the average pause. (1)

Question 9. Why is the development of a wide recognition span important in developing efficiency in reading?

Answer. A wide recognition span relieves the mind of a detailed form of word analysis and makes possible the focussing of consciousness on the processes of interpretation.

Question 10. May the rate of recognition be improved by immature readers in the upper grades?

Answer. Yes. (10) Photographic studies of eye movements indicate that training in recognition may prove effective in the case of upper grade pupils who have not attained mature habits in this respect.

Question 11. What causes irregularity in perception?

Answer. Irregularity as measured by the number of regressive movements has four major causes: (1)

(a) failure to reach the desired position at the beginning of the line after the backward sweep of the eye from the end of the preceding line
(b) overreaching the recognition span
(c) inadequate word recognition
(d) random oscillation of the eye, due possibly to lack of grasp or to analysis of one sort or another.

Question 12. In oral reading do the eye and voice reach the same position on the line at the same time?

Answer. The eye and voice of the beginner reach the same point at about the same time. With maturity, the eye precedes the voice.

Eye span increases rapidly during the first four grades, and for the good reader reaches maturity during those grades.

Question 13. Do eye movement patterns exhibited in reading and answering objective questions follow the eye movement patterns characteristic of ordinary continuous reading?

Answer. The eye movement patterns exhibited in reading and answering objective questions differ (8) most from those characteristic of ordinary prose reading in the more analytical nature of the former; for the questions, the sequence of fixation is more irregular and pauses are both more frequent and longer. The patterns range from rather prose-like progression to an irregular series of oscillations suggestive of the reading of isolated formulae.

Question 14. Are there fundamental differences in the eye movements in reading English and in reading foreign languages?

Answer. Foreign languages should be read with the same regular forward movements characteristic of good reading of English. (2, 13)

Even in reading Chinese, mature readers exhibit a pattern similar to that of mature readers of English, except that vertical movements replace horizontal movements.

Question 15. What characterizes eye movements in reading music?

Answer. The eye movements of mature and immature readers of music (14) are similar to those for other types of reading with respect to number of notes and chords in music. Differences in rhythmical patterns of the two clefs and other complexities tend to increase the number and duration of fixations.

Question 16. What characterizes the eye movements in looking at pictures?

Answer. The initial period is characterized (5) by a series of short fixation pauses indicating a survey of the whole. This is typically followed by a series of fixations longer in duration, usually centered about major features of interest.

Question 17. In arithmetic problems, does reading proceed faster when numerals or their equivalent words are used?

Answer. The use of numerals in place of words in arithmetic problems tends to increase the speed of reading. (15)

Question 18. What eye movement pattern characterizes the learning of spelling words?

Answer. Typical progression consists of left to right movements across the word, probably (9) repeated a number of times. Concentration of fixations may occur near a point of difficulty. With maturity, there is a decrease in the number of progressions across the word, the number of fixations (including regressions), and in the duration of pauses.

Question 19. What characterizes eye movements in typewriting?

Answer. The eye-hand span in typing at about 40 words per minute is about one word. Among the most rapid typists this space is about 1.5 words. In most (6) cases there is a tendency to set a time space of about 1 second. The average number of fixations varies from 16.3 to 26.3 per line.

Before concluding this paper the fact should be emphasized that this set of questions and answers is not to be regarded as a comprehensive summary of findings in the field of eye movement habits. It is intended, rather, as a brief exploratory treatment of a few important findings in a most important field.[1]

[1] See Appendix B for references.

Section VIII

COURSE OF ACTION FOR THOSE WHOSE VISION IS VERY DEFECTIVE OR LACKING

Most that has preceded concerns chiefly the best utilization and conservation of normal sight. Teachers, school officials, and nurses, parents, and others directly in charge of children or interested in visual welfare sometimes are confronted with the problem of what to do specifically in the case of a child or other person of failing sight or whose sight is gone beyond repair. The word *conservation* applied to border-line cases, where the chances of improvement are slight and the best that can be done is to keep what remains, really covers only a very restricted segment of sight conservation and a new word should be found for the classes and procedures covered by the older usage. In this section, unless otherwise specified, the term will be used in this restricted and almost technical sense.

In earlier practice only those totally blind, or nearly so, were regarded as needing ''special education.'' Gradually it was realized that children who could not see the blackboard, who were unable to read ordinary print with ease, and who could not carry on ordinary seeing tasks in comfort were as handicapped in many respects as those who were blind. It was largely the pioneering of the National Society for the Prevention of Blindness that brought about the recognition of the needs of this group and their partial segregation under improved conditions for their education. So also the National Society has been a major agency in setting up standards of equipment and procedure for special classes in sight conservation. They have been instrumental, too, in urging legal provision for such classes.

The public schools of New York City have the most thoroughgoing provision both for classes for sight saving and for special teacher training for such classes. A number of states and city systems have followed the lead of New York in the setting up of classes and of standards of instruction. In most states the provisions are either lacking or vague beyond reason. In some the school law or school code sets up general provisions for handicapped children and makes special provisions specifically or by implication in a paragraph or section.

Section 3.625 of the California School Code reads as follows:

> The instruction of physically handicapped individuals may be provided through special classes or through the employment of home instructors, and by any other method or methods approved by the State Department of Education. *For those with defective or diminished vision, sight saving classes may be organized in addition to any other methods used.*[1]

A digest of the whole section is necessary for arriving at the specific set up; it is assumed that all general provisions apply specifically and large discretionary powers are left with the State Department of Education. In effect, this Department can make a very specific set-up under the general provisions of this and other sections, to the extent of prescribing all standards of training and of procedure. This allowance of latitude is probably better than the statutory specifications of certain other states and of previous California enactments.

In practice the local community largely determines its own set-up and procedures. Thus, the Los Angeles public schools have made as complete and effective provisions for sight saving classes as any school system in the United States. The San Francisco public schools also make excellent provision for sight saving classes. Cities of less population find it rather difficult to assemble a sufficient number of children in one school to justify the effort but in three or four cases they have started classes and done acceptable work. The state yet lacks adequate central machinery for aiding local communities in this type of sight conservation work.

The standards have to do first with teacher preparation, second with rooms and equipment, and third with cooperative arrangements. Unless approved standards are fairly rigidly fulfilled, mistakes may be made that will vitiate the work done and render it more harmful than useful.

In general, only those fully prepared for regular public school teaching should undertake sight saving work. They should have at least two, and better three, years of experience in classes of normal vision. Then they should have a course in the physiology of vision. The most important training relates, of course, to the technical side of teaching and class management: the use of the special typewriter, and the technique of handwriting for conservation purposes. Teachers should be chosen and trained rather than trained and then put into this special class work.

The room chosen for a sight saving class should be specially tested for lighting. No room which has not a high level of natural lighting throughout should be selected and devices should be selected and installed to keep the lighting uniformly at a high level. In cases where eye defect is accompanied by photophobia the individual child

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[1] Italics inserted by author.

should be singled out and given special attention as to dark glasses, seating, etc.; the class as a whole should not be made to suffer. All equipment should be chosen with extreme care. Books must be of the sight saving type such as those published by the Clear Type Committee of Upper Montclair, New Jersey. There are a few books from general lists with special type, large and clear, which may be used in individual cases; but, generally speaking, there is little use of segregation unless the special standards can be maintained. This applies to typewriting, handwriting, and arithmetical notation as well as books. It should apply in music, but little has been done in this direction.

Most important of all in any effective program of sight conservation is the assignment of pupils to regular class work and the follow-up on the part of the special teacher to see that standards are conformed to and work properly accomplished. The main purpose of keeping sight conservation groups in the regular public school organization is to have the children do regular class work as much as possible. Complete segregation for all work would defeat this purpose. While segregation has prevailed in work for those technically blind even in the public school organization, the chances for effective work in sight conservation are increased by close correlation of class work and activity programs with the work of children of normal vision. Segregation is tenable from the educational point of view only when it forms the last resort for the effective education of any group or when their education so seriously interferes with normal programs as to create a distinct loss in the school organization.

Provisions for the education and rehabilitation of the partially and totally blind in California are as follows:

Schools. The state maintains a residential school in Berkeley. This school is open free of charge to all blind or partially blind minors, resident in California, who have not completed the regular public high school course or its equivalent. Also those having completed a high school course who desire further work in music may attend the state school for a term of two years. The California School for the Blind provides regular public school courses from the kindergarten through the twelfth grade of the high school. Its teachers and supervising officers are specially trained for their work but nearly all have had regular public school experience and all keep in close touch with educational progress in other fields. The vocational work and music courses supplement the regular classes. Mentally backward children are given special attention.

The school is equipped very completely with library facilities, maps, globes, and models for objective and effective instruction in all regular classes. The music department has equipment equal to that

of a small conservatory of music. The shops are adequate for effective general hand training. Recreational facilities are exceptionally good, with emphasis on the boy scout program and out-of-door activities. The residential provisions and medical care are incidental to the school program.

The Los Angeles public schools provide classes for the blind through the grades. Those of high school age attend as a rule a selected high school with continued guidance and special reading but no segregation. The provisions for blind children in the city system are among the best in the United States. Younger children have exceptional advantages in the provision of library facilities, music, and recreation. In both Pasadena and Long Beach provision is made for class work for blind children, but neither city has the advantages in classification and equipment that go with larger numbers.

Rehabilitation. Those losing their sight after school age or those blind who wish special vocational education may receive special aid through the Bureau of Rehabilitation in the Department of Education, with offices in the State buildings in Sacramento, San Francisco, and Los Angeles. Work in vocational fields is also conducted by the field officers and shop centers (Oakland and Los Angeles) of the Department of Institutions, Division of Institutions for the Blind.

Library. The State Library at Sacramento has a large collection of free literature in all now used systems of embossing. All books can be sent through the mails free and may be secured by any blind residents of the state or even by residents of other states on application. The Library maintains in addition a teaching service for adults and "shut in" or preschool children, with a field teacher in San Francisco and one in Los Angeles.

Detailed information on *State Services for the Blind in California* may be had in a little booklet of that title from the California School for the Blind, Berkeley; the Bureau of Rehabilitation, State Department of Education; or the State Library, Sacramento, on application.

Section IX

LIGHT AND SIGHT IN TRAFFIC

So many light and sight factors are involved in all forms of transportation that even a brief discussion would necessitate a long, technical chapter. The actual sight conservation factors are more limited but in automobile driving particularly they are so involved with other factors that it is hard to separate them. In what follows, therefore, the conservation factors are always implied and automobile driving is under consideration, unless specific mention is made of other types of traffic. Also, the implication is always present that the effective use of sight is what is mainly involved and that conservation goes beyond the ordinary connotation to imply not merely the saving and utilization of vision but its part in the preservation of life and limb and of sane mentality.

Strictly speaking, the main conservation elements involved are shielding the eyes from glare, preventing serious fatigue, and avoiding conditions of lighting, dust, gas fumes, and prolonged strain that may lead to irritation and bring on serious eye troubles. The answer to most of the exactions of driving is twofold; the one of avoidance when and where possible; the other, material and technical provisions to meet unavoidable conditions. Thus fatigue can be met by intervals of rest; the extreme glare of the late afternoon need not be faced, if hours of travel and direction of travel are properly planned; one can for the most part stay off dusty roads; and irritating gases can be largely eliminated by proper attention to mechanical conditions. If, on the other hand, one must drive under conditions of glare he can wear colored glasses properly made and fitted. If it is imperative that long distances be covered in short periods of time, there can be an interchange of drivers, or the one driver can increase speeds over safe stretches and gain time for rest and eye-relief by his intelligence and sanity of management. In most cases speed is not required nearly so much as drivers imagine. Planning ahead will almost invariably eliminate the necessity of long-continued, eye-fatiguing driving.

Highway engineers and street departments are trying with more and more gratifying success both to improve highway surfaces and to bring signs and lighting into conformity with best practice as determined by scientific investigation. Dark and non-reflecting surfaces in the highway itself, with strongly contrasting markings in white meet seeing needs best for daylight driving; at night concrete pavements

with a reflection factor up to 25 per cent increase visibility. The central white line or white traffic lane markings help the driver the keep his place with less attention and less need of muscular control than is possible on unmarked roads or highways. Few and very obvious signs, with a minimum of lettering, are better than a multiplicity of signs; misleading signs for advertising purposes, such as, STOP !—HOT DOG STAND 500 FEET, should be wholly barred from highways as much as obscuring fences, hedges, and other obstructions to vision. The symbolic forms of information or direction such as the conventional curve signs are much more effective than worded signs. On all the contrast factor is important, best perhaps black on white. Reflectors serve only at night but are very effective if properly placed. Perhaps a code of simple symbols should be developed and then committed to memory by all drivers. Warnings of obstructions, changes of direction, slippery pavements, and so on, should be placed decidedly in advance and be highly visible and instantly intelligible. In this respect the California highways set a model for the nation. The use of red on white for danger symbolism strikes the writer as of dubious value. The contrast factor is decidedly lowered and in the case of small lettering the sign may become all but unintelligible at safe speeds to say nothing of higher speeds.

No amount of signs and no degree of proper lighting can do away with the necessity of quick and intelligent reaction. Most fatal accidents are the result of imperfect reaction due to stupidity, lack of training, fatigue, or drug effects, notably alcoholism. Reaction examinations have not yet been fully developed but should be; and all who cannot pass reasonable tests should be barred from highway driving. It is to the driver's own advantage to train himself or be trained in seeing clearly in advance, detecting relatively small objects in his path and learning to respond with speed and precision. Thus, a nail or jagged piece of bottle seen and avoided may mean the avoidance of a puncture or even a blowout. The detection of a slippery spot in advance may mean avoidance of a dangerous skid. How all-important are quick visual detection and precise response is shown in the fine record of safety made by deaf drivers where visual factors alone can offer warning. In particular the critical situation demands not only good sight and trained sight but a close correlation of sight, brain, muscle in an almost instant response. Many a fatal accident could have been avoided had the quick, trained intelligence factor been even a small fraction higher. Quick seeing, not merely reaction-time which is irreducible beyond a certain point, but quick seeing with responsive intelligence behind it, is important beyond possible estimate.

Obedience to traffic laws and regulations need hardly be mentioned to good citizens. One is likely to forget, however, that these laws and regulations have grown out of reasoned experience, often with actual tests of vision and reaction that lend a rational element, instead of the tradition we are likely to think of as back of law. Thus 15 miles per hour speed limits may appear stupid when one has a powerful, heavy, and well balanced car in perfect mechanical condition. The limit seems rational enough, however, when the general run of traffic at dangerous crossings or around sharp curves is considered. At speeds in excess of 45 miles per hour the lettering of signs becomes less and less legible, the possibility of response to signals is lessened to an alarming degree, and the probability of catching small but perilously significant changes in roads surfaces, direction, etc., drops lower and lower. The tire marks on curbs, the broken down grade barriers, the wrecks of machines in ditches and canyons tell the story of the ineffective use of sight and of the delayed response. Disregard of signs due to speed or any other visual failure due to speed may bring an all too swift penalty in some easily avoidable fatality.

Traffic lighting is too technical a subject for treatment here. The driver and the prospective driver can only be warned as to the absolute necessity of good sight and intelligent foresight, plus obedience. No lighting of highways will ever approach perfection and the most nearly perfect lighting of highways will never offer a foolproof substitute for good vision with high intelligence backing it.

The following notes on driving under conditions of low visibility reinforce what has already been said and supply certain technical details to both those who drive and those who would inculcate good and careful driving habits.

DRIVING UNDER CONDITIONS OF LOW VISIBILITY [1]

The most common fault of the average driver is overdriving the headlights. Overdriving the headlights means driving too fast to stop the car within the distance ahead illuminated by the headlights. Records indicate that a driver has his headlights inspected on the average of once every fifteen months. In that period there is a very marked depreciation in the efficiency of the headlamps. Headlamps capable of generating 50,000 candle-power after a year's operation have been found in some cases to produce as low as 6000 candle-power. By cleaning the reflector surface and the lens the candle-power can be raised one-third or more. The lamps should be carefully checked for cleanliness and adjustment at least every four months.

[1] Adapted from notes of Dr. Hugh V. Brown.

The following test of the headlight performance of 38 cars as reported by H. H. Magdsick shows typical depreciation and possible improvement.[2]

Headlighting Performance as Disclosed by Tests on 38 Cars

Age of car	Less than 1 year	1-2 years	2-3 years	3-4 years	More than 4 years
Maximum beam candlepower as found	18,410	16,500	9,100	5,260	5,100
Maximum beam candlepower after cleaning lenses	19,200	18,260	10,190	5,970	5,900
Per cent increase	4.1	11.1	11.2	11.3	11.5
Maximum beam candlepower after cleaning reflectors	23,900	23,200	17,940	12,840	11,000
Per cent increase	30	41	97	144	120

P. H. Goodell[3] found that few cars had maximum beam candle-power exceeding 10,000 and that the average was about 6000 candle-power. With automobile headlights having a candle-power of 6000 he found the following visibility distances at a speed of 40 miles per hour.

Object	Visibility Distance
Dark, 4 per cent reflection factor	105 feet
Medium, 12 per cent reflection factor	120 feet
Light, 29 per cent reflection factor	180 feet

Increasing the beam candle-power increased the visibility irrespective of the reflection factor of the object, each additional 15,000 beam candle-power adding 35 feet to each visibility distance.

Statistics show that the death rate during the evening rush hours (the zero hours) is twice as great in the winter as in the summer even though there are 25 per cent more cars on the road on summer evenings.

All the preceding discussion has been of visibility when atmospheric conditions are ideal. Smoke generated by faulty combustion in cars and trucks ahead, fog, mist, rain, sleet, and snow all add their factors that must be considered. In California during the winter months, fog is a particularly important factor. When fog is coupled with dirty windshields, dirty lamps, and low candle-power output, extreme caution is necessary. *Be sure not to overdrive the headlights.*

The chart in Figure 12 shows minimum stopping distances; also the distance covered during the mental reaction time as a function of speed. This chart shows that at a speed of 40 miles per hour one travels approximately 40 feet after seeing an obstacle before he can react and set the brakes and that the car travels a total distance of 120 feet after one sees the object before the car is stopped. Considering that with 6000 candle-power headlights one can see dark objects only 105 feet away, medium objects at 120 feet, and light objects at 180

[2] Paul H. Goodell, "Street Lighting and the Science of Seeing," *Transactions of the Illuminating Engineering Society,* XXX (January, 1935), 75.
[3] *Ibid.,* pp. 57, 58.

feet, one sees the need for having at least 21,000 candle-power lights for 40 mile per hour speeds in which case the visibility distances are 35 feet more, or 140, 155, and 215 feet respectively. Arthur J. Sweet[1] maintains that at 40 miles per hour safety requires that a hazard on the highway be discerned at least 200 feet away. He considers auto headlights inherently inadequate for safety at such speeds, adding that highway lighting is an absolute necessity for safe night driving unless speeds are limited to approximately 30 miles per hour.

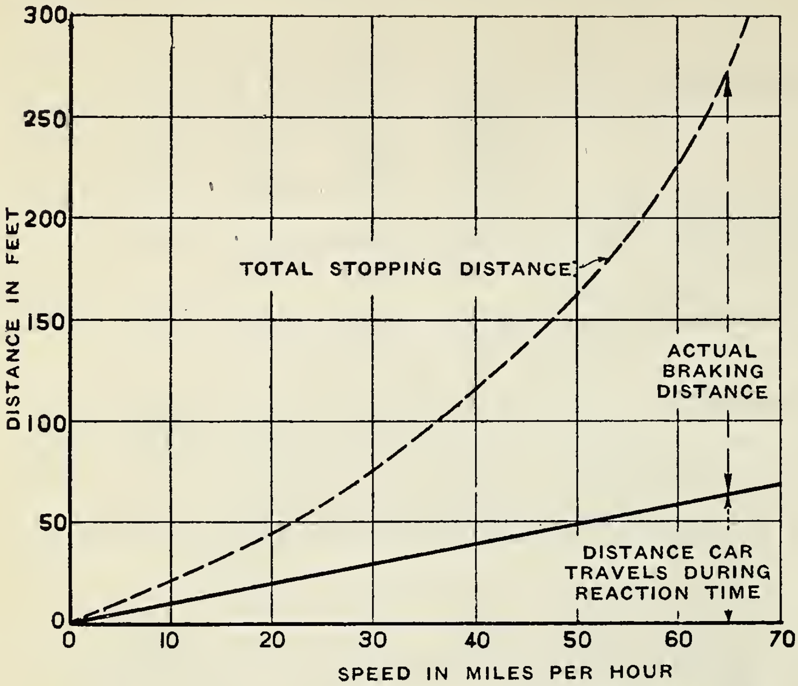

Figure 12. Stopping Distances at Varying Speeds for Automobiles

Hand Signals

Hand signals at night must be given with unusual thoroughness. A hand or arm moving up and down is much more likely to be seen than one held motionless. A light yellow pigskin glove on the left hand is more likely to catch the eye than a bare hand. It is imperative to watch in the mirror to note that the driver behind has seen or has not seen the signal. If the driver slows down, all right; if not, it is your responsibility to gauge your actions accordingly for it is far cheaper to waste two or three seconds than to pay for new parts for your disabled car.

Reaction Time

The degree of coordinate activity between the eyes, hands, and feet is conditioned by many factors: age, experience, attention, physical handicaps, fatigue.

There are no major mechanical problems in the operation of a new model automobile. The demands of modern traffic congestion require perfect or at least near perfect coordinations. Only through the exercise of these coordinations are accidents avoided. It is now possible with

[1] Arthur J. Sweet, "Fundamentals of Rural Highway Lighting," *Transactions of the Illuminating Engineering Society*, XXXI (May, 1936), 489.

newly perfected testing equipment to measure the reaction time of the various coordinating reflexes and also to estimate the potential increases in reaction time that may be induced by fatigue. These include threshold level of illumination for detail discrimination, pupillary reaction time to light and dark adaptation, coordinate eye movements (versions), hand and eye coordinations, foot-hand-and-eye coordinations, visual-auditory and auditory-visual-motor coordinations, convergence-accommodation rate, quality of binocular vision. There are also many other tests that are conditioned by the I. Q. level.

The application of the above tests has enabled the California State Department of Motor Vehicles to state that the average driver requires three-fourths of a second in which to start applying his brakes. Highway marker signals and signs are placed at specified distances from the scene so that if the driver is traveling at a speed within the legal limit, he will have adequate time to adjust the speed of his vehicle

Further to insure sane operation, in many cities the major streets are marked into definite lanes for travel, crosswalks and school crossings are designated by zigzag lines instead of parallel lines, signs upon the pavement are designed to be legible at specified road speeds.

Signs

The experiments on the legibility of type for best reading practice has direct bearing upon the design of highway marking signs.

Extensive tests have demonstrated that while the average ideal driver uses about one-half second in reacting to apply his brakes, many drivers need as long as three or four seconds, or more. This characteristic must be taken into consideration when designing highway signs and markers. Markers must be visible at from 500 to 700 feet. This will give the individual adequate distance to react even though he may be traveling at 40 m.p.h. Experiments have established that letters to be visible when in a sign in a vertical position must be 12 inches in height; one with 20/30 vision can distinguish detail only two-thirds as far as one with 20/20 or normal vision, and should accordingly keep his speed in driving within such limits as to be able to stop in safety. One with 20/30 vision can, for instance, read the old type standard highway sign with 6-inch lettering at about 150 feet in average light as against 220 feet for the person of normal vision. Under conditions of low visibility, lack of visual acuity may demand more than the usual precautions, due to complicating factors; that is, lack of acuity is not simply a matter of percentages with corresponding percentages of caution demanded, but the whole visual complex is affected in any case where conditions demand normal powers and the actual powers are below normal. Drivers with lowered acuity may

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actually be safer drivers, due to increased alertness and other compensating factors; but the general assumption must be maintained that any serious loss of acuity should bar an individual from driving.

As to field of form and motion, while a person's greatest visual acuity for details is straight ahead, his ability to detect motion is just as great or greater at the side, the retina of the eye having a higher and higher percentage of motion perceptors as we get nearer to the edge. It is this ability which makes it possible to watch the road intently in front and still see a car approaching from the side.

Without going into details of the test, which is easily and quickly made, it means that the driver successfully passing the test would be able to detect a moving object approaching an intersection or any point on the road ahead of him within the limit of his vision, while it is still twice as far away from the point as he is. A person of normal vision can detect motion with either eye at an angle of 90 degrees temporally, and nasally until the bridge of the nose interferes. Practically, a driver with 20/30 vision and a side field of 64 degrees for a one degree test object can see a car approaching an intersection ahead of him in average light when he is still 150 feet from the intersection and the other car is 300 feet distant from it. This gives him ample time to turn his eyes, look directly at the approaching car, judge its speed, and make his decision to pass or stop. It must be emphasized that it is not merely the picture which the eye presents to the driver which counts, but what that picture means to him, what he knows should be done about it, and whether he is willing to do it. The stereopsis test is a test of a driver's ability to judge distance and depth, and corresponds to the tests made for aeroplane pilots. Not nearly so fine a rating is required here as for the aeroplane pilot, where misjudging his height by one foot in coming in for a landing may be fatal, but some degree is absolutely essential. Only in this way is it possible to judge the relative speed of an approaching car and determine whether or not it is safe to pass another vehicle, round a curve, or cross an intersection. Lack of this ability accounts for many accidents which are otherwise inexplicable. Seventy per cent stereopsis or better has been recorded in individuals having vision as low as 20/60 in one eye and 20/40 vision in the other, and totally absent in other drivers having 20/30 vision in each eye. If not originally present this ability can be developed by droper training in almost all cases. Certainly no one should be allowed to drive without it, and those in whom this ability is weak should know their deficiency and exercise double precaution. This is a binocular test, depending upon the functioning of both eyes. A 70 per cent rating is the minimum safety requirement regardless of the vision which may be obtained with either eye independently.

SOME CONCLUSIONS

The world of our ancestors was not a reading world. It was not a world of artificial light. The appeal to the eyes through signs, highway markings, billboards, cinema, etc., was wholly lacking. Alphabetic letters have been known probably not more than five thousand years, paper making dates back only a few hundred, printing cannot yet celebrate its five hundredth anniversary and electric lighting, the cinema, and the illustrated magazine and newspaper are only of yesterday. Our relatively recent ancestors told stories or listened to them and proclaimed their news on the street corners. While eyes were in constant use then as now they were occupied mostly with coarser tasks in the light of day. It is hard for us to realize that until recently most people arose at dawn, did all their work or nearly all under conditions of normal daylight, and retired soon after dusk. Few read at all and those few for most part read aloud, at a rate that involved none of the strain of present day rapid silent reading. Eyes were rather partners in a world in which speech and hearing played a much larger part than at present. No such exactions were put on sight as visual instruction, flickering high lights, high speeds, glaring street pavements, and street signs, and all the devices of visual appeal now make. At the worst, change and rest were frequent and correctives were far less needed than now.

Under present day conditions the struggle for the very preservation of vision becomes a desperate one. Each year more children and young people wear glasses. Effective examination reveals a greater and greater percentage of visual ailments and visual defects. Overstimulation in the form of speed, incorrect lighting, cocktail parties, night clubs, and all the hectic devices of a pleasure mad world lead to an unbalance which is the major danger of present day civilization. The clear eyed sanity of our fathers can not be recalled, however, by backward steps. Conservation in its broader aspects must begin with the earliest years and continue as a main factor in training and practice throughout life; conservation of every resource, health, strength, good appearance, nerve-energy and mental balance and most notably what has come to be the main and often the sole channel of mental and emotional appeal, vision.

It should always be remembered by educators, physicians, parents, lighting experts, optometrists, printers—in short by all who have to do with sight—that practically all conditions of visual impairment are preventable if taken in time. Equally it should always be remembered that all conditions putting an unnatural strain upon the eyes, bad lighting, poor print, etc., become potential factors in the impairment or loss of sight. What can be done by taking thought and

preventive measures is shown in the splendid record in all highly civilized countries in the virtual elimination of *ophthalmia neonatorum*. What physicians and nurses have done in this restricted field can be done for general eye comfort and eye welfare by the concerted efforts of the many persons most concerned in the increasingly larger field of eye hygiene.

Not only should general preventability be stressed: it should almost equally be emphasized that eye comfort and eye health are closely correlated with general health and efficiency. The relation is, of course, reciprocal and a lowering of visual acuity or other eye troubles may result from indigestion, the use of drugs, lowered health tone, or acute illness equally with the possibility of general upset, headaches and nausea from eye strain or from shock resulting from visual impairment. An increase in the size of type, greater line clarity in the type itself, and increased contrast as between print and paper can sometimes make the difference between a backward and subdued child and a reasonably alert and normally progressing child. A favorable change in lighting, fitting with proper lenses, a change of diet in certain eye conditions, in fact many simple steps properly taken, on correct and scientific advice, may make a well person and an interested and intense person out of an ailing, lackadaisical being with the common signs of potential mental or physical invalidism. Narrow specialists are likely to forget these major correlations.

In closing, it seems desirable to call attention again to the enlarged meaning of the conservation of sight which is taking the place of the restricted interpretations of the earlier movements. Since the time of Theodore Roosevelt conservation has meant *effective utilization with a minimum of destruction and waste.* If the program of the great conservationist President could be applied to everything that has to do with eyes and sight, salvage would be less necessary and general human comfort and well-being would be advanced beyond the dreams of the earlier sight conservationists. The matter is one for real concern and for general rather than restricted and specialist interest. And all concerned must join in a concerted effort to save and to utilize effectively the most precious of the senses.

APPENDIX A

RELIABLE SOURCES OF INFORMATION ON LIGHTING, WITH ANNOTATIONS

Leland H. Brown, Stanford University

Periodicals

The American Architect

Devoted to the problems of the architect.

Authoritative and excellent articles on lighting applications are often published in this journal.

The Electric Journal

The technical publication of the Westinghouse Electric and Manufacturing Company.

Most technical developments of the Westinghouse Company are first reported in this journal.

Electrical Engineering

The official publication of the American Institute of Electrical Engineers.

An excellent technical article on lighting appears in approximately alternate issues of this publication.

The Electrical World

A technical journal devoted to the electric power industry, published every two weeks by the McGraw-Hill Book Company, Incorporated, New York, N. Y.

Every issue usually has one or more brief articles on lighting. Stress is usually laid upon applications and economics though new developments are always briefly summarized.

Electronics

A technical journal published by the McGraw-Hill Book Company, Incorporated, which covers the entire field of electron tube devices and instruments.

Photoelectric phenomena and devices and vapor tube sources are described in detail. The publication stresses the description and operation of the devices rather than applications.

General Electric Review

A technical publication of the General Electric Company.

Most technical developments made by the General Electric Company are first described in detail in this journal.

The official publication of the British Illuminating Engineering Society.

Probably the best European publication devoted exclusively to lighting.

Magazine of Light

A semi-technical advertising publication of the General Electric Company.

Popular articles regarding lighting developments and the results of research on lighting applications are summarized. It is a good publication for keeping in touch with lighting practice and is designed primarily for lighting salesmen.

Scientific Papers of the Bureau of Standards.

Transactions of the Illuminating Engineering Society.

This is published monthly by the Illuminating Engineering Society of 29 West 39th Street, New York, N. Y., and is the most authoritative and comprehensive publication in the United States on lighting.

Books

Illuminating Engineering. Edited by Francis Elmore Cady and Henry Baldwin Dates. New York: John Wiley & Sons, 1925.

One of the best texts on Illuminating Engineering, but unfortunately rather out of date, being 8 or 10 years old.

Higbie, Henry H. *Lighting Calculations.* New York: John Wiley & Sons, 1934.

A very complete assembly of excellent illumination problems collected from current lighting literature by the author over a period of perhaps ten years. References are given in practically every case. A small amount of text material accompanies the problems but in general the problems have to be solved if the reader is to get much of value from the book.

Walsh, John W. T. *Photometry.* New York: D. Van Nostrand Co., 1926.

Probably the most authoritative and complete treatise on photometry ever published. One of its features is a very complete bibliography at the end of each chapter.

Luckiesh, Matthew

Color and Its Application. New York: D. Van Nostrand Co., 1921

Light and Shade and Their Applications. New York: D. Van Nostrand Co., 1916

Artificial Light, Its Influence Upon Civilization. New York: Century Co., 1920

Lighting Fixtures and Lighting Effects. New York: McGraw-Hill Book Co., Inc. 1925

Light and Work. New York: D. Van Nostrand Co., 1924

Artificial Sunlight. New York: D. Van Nostrand Co., 1930

Seeing and Human Welfare. Baltimore: Williams and Wilkins, 1934

The Standard Handbook for Electrical Engineers. Edited by Frank F. Fowle. 6th Ed. New York: McGraw-Hill Book Co., Inc.

This is an encyclopedia of electrical engineering revised periodically. The section of Illuminating Engineering is an excellent summary of the illumination art. A complete bibliography is included.

Kunerth, William. *A Text-book of Illumination.* New York: John Wiley & Sons, 1929.

A rather elementary text quite suitable for an introductory course in illumination.

Bulletins

The scarcity of textbooks in the field of lighting has resulted in various manufacturing companies such as General Electric Co. and Westinghouse Electric & Manufacturing Co. publishing non-commercial bulletins on lighting. These have been written by well known authorities in the field of illumination and are constantly being revised to conform with the developments in the illuminating art. These non-commercial publications constitute one of the most valuable sources of reliable information.

APPENDIX B

REFERENCES ON EYE MOVEMENTS IN READING

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